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#223 DECEMBER 2023

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SCAN THE QR to discover more!

Welcome

Enjoy a winter Grand Tour of our giant outer worlds

There's a treat for stargazers this December – all four of our Solar System's outermost planets, Jupiter, Saturn, Uranus and Neptune, will be visible spread out on a line, like beads on a necklace. This is a great opportunity to follow in the footsteps of the Voyager probes' Grand Tour and explore these gas and ice giants for yourself. Turn to **page 30** for Stuart Atkinson's easy-to-follow guide on how to track them down with the naked eye, binoculars and small telescopes.

These far-off worlds will be better seen the more magnification you use, and training a telescope on Jupiter and Saturn can show you some stunning details. Eyepieces are the crucial accessory here, and on **page 66** Tim Jardine takes a look at the wide array of options on offer. Check out his advice on what to consider for clearer, close-up views.

When you observe the four outer planets, you'll be seeing them as they were in the recent past – the light from Neptune, the Solar System's outermost planet, for example, takes up to four hours 20 minutes to reach Earth. The light from objects further away, like stars and galaxies, takes much longer. Amazingly, astronomers can trace light right back to a time just after the Universe was created. This, the first light to spread through the cosmos after it formed in the Big Bang, is known as the cosmic microwave background, and on **page 36** Ezzy Pearson describes the remarkable story of how it was discovered and what it tells us about space and time.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 14 December.

HOW TO CONTACT US

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Sky at Night – lots of ways to enjoy the night sky...

Television

Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18

Online

Visit our website for competitions, astrophoto galleries, observing guides and more

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Podcasts

Discover the best things to see in the night sky every week by listening to our Star Diary podcast

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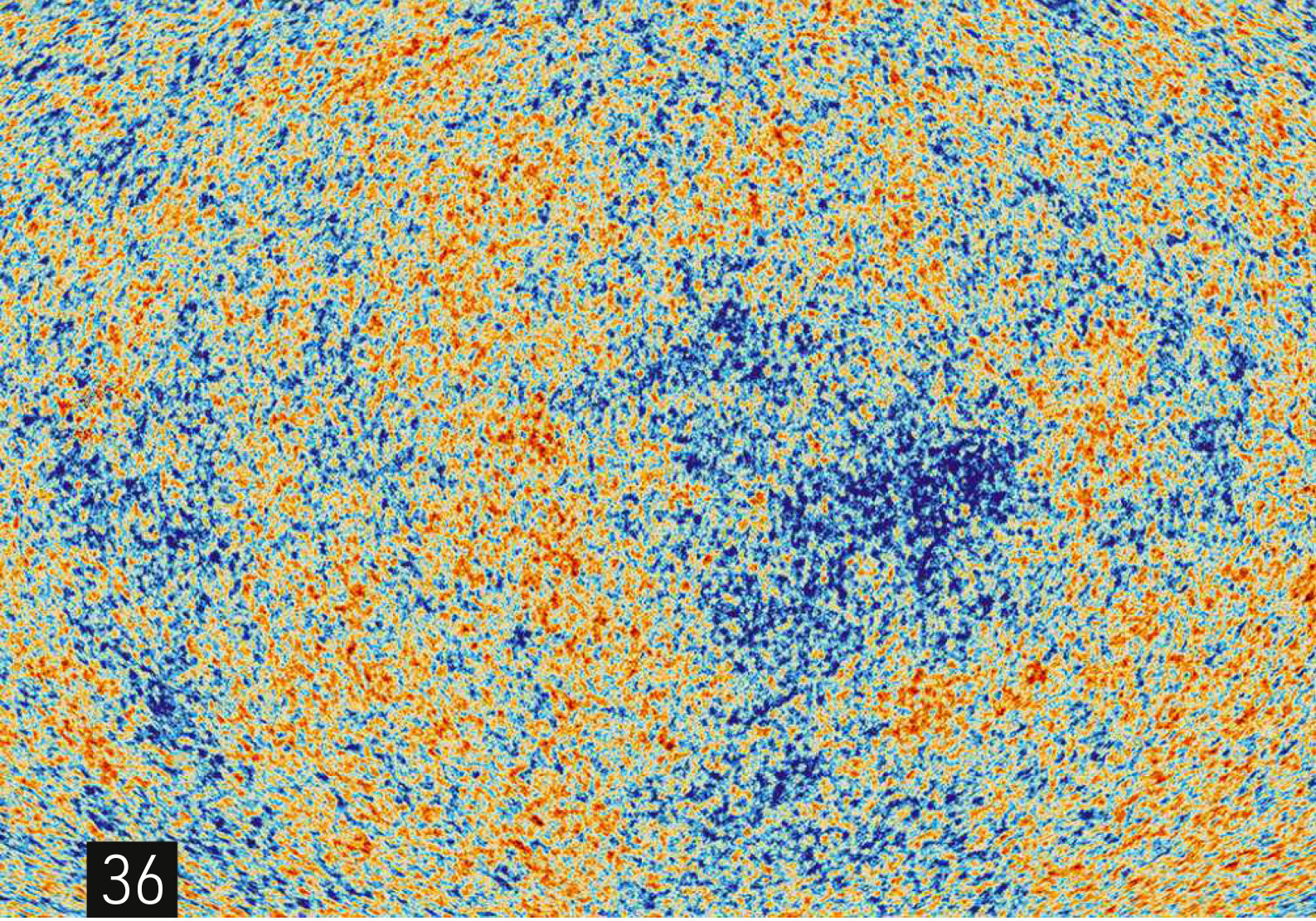

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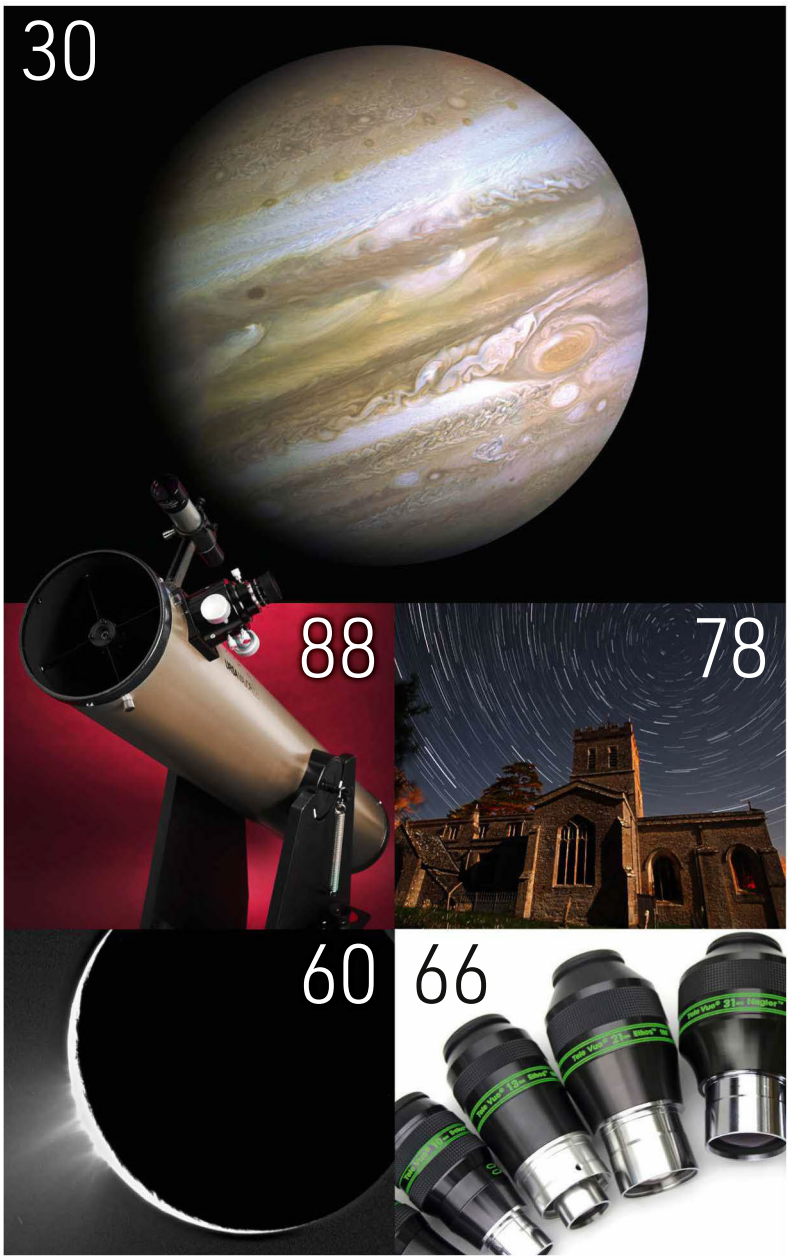
16-PAGE CENTRE PULLOUT

COVER IMAGE: MARK GARLICK, THIS PAGE: ESA AND THE PLANCK COLLABORATION, NASA/JPL-CALTECH, @THESHED_PHOTOSTUDIO, MARY MCINTYRE, NASA/JPL/SPACE SCIENCE INSTITUTE, TIM JARDINE, BBC, MARK PARRISH

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Ezzy Pearson

Features editor

"The afterglow of the Big Bang is all around us in the form of the cosmic microwave background. Picking it out, however, can be somewhat challenging." **Read how the CMB reveals the secrets of the cosmos on** page 36

Penny Wozniakiewicz

Planetary scientist

"Water isn't just found on Earth, it's abundant across our Solar System. What's more, it could be vital for the future of crewed spaceflight and the search for life." **Why astronomers search for water,** page 60

Tim Jardine

Kit expert

"Decent eyepieces are a vital part of any telescope setup, but with so many options to choose from it can be difficult to make a decision about what's best for you." **Find out how to build your own collection on** page 66

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/beifbpt** to access this month's selection of exclusive Bonus Content

DECEMBER HIGHLIGHTS

Interview: Fighting light pollution

Dark Sky Officer Dani Robertson reveals how artificial light affects our view of the night sky, and how to fight it.

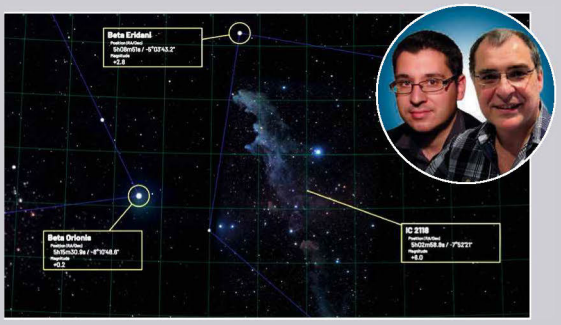
***The Sky at Night* Question Time Special**

In this hour-long special, Maggie, Chris and Pete join a panel of experts to answer questions on space and astronomy.

Make a model to show Venus's phases

Download and print out our plans and guides to help you complete this month's DIY astronomy project, on page 74.

The Virtual Planetarium



Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

THREE'S COMPANY

Galaxy pair Arp–Madore 2339-661 is actually a galaxy trio

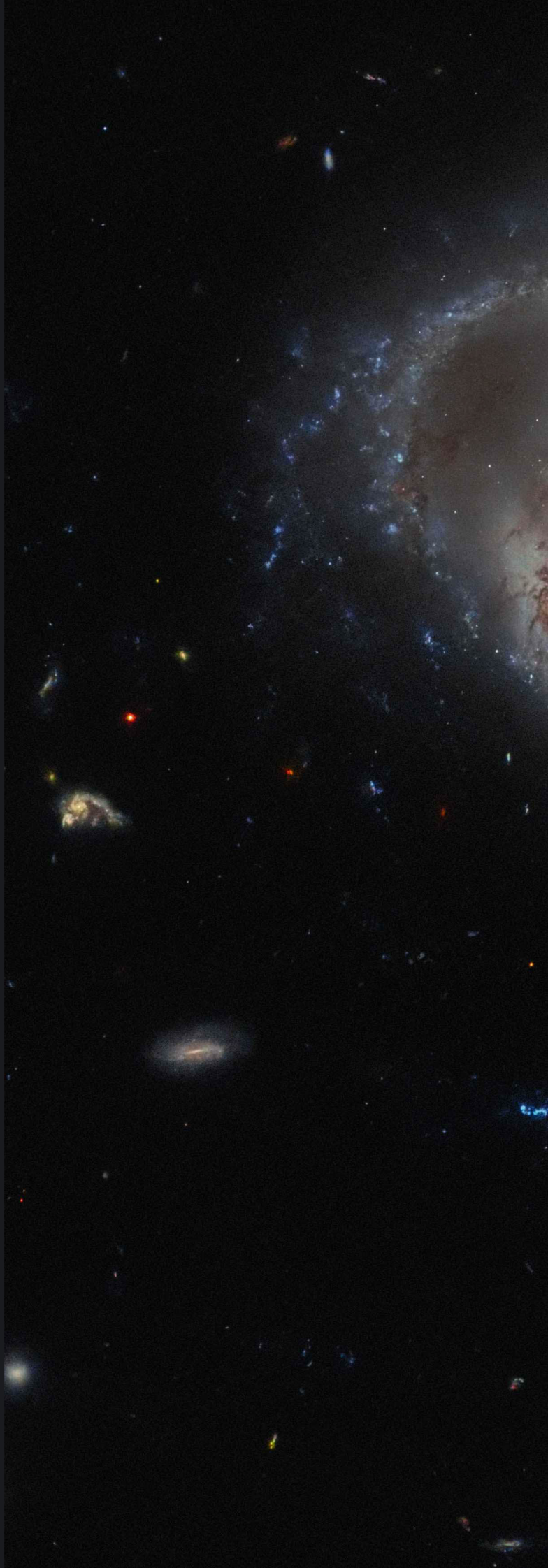
HUBBLE SPACE TELESCOPE, 23 OCTOBER 2023

Individually, the two galaxies in this image – which lie 500 million lightyears from Earth in the constellation of Tucana – are known as NGC 7734 (top left) and NGC 7733 (bottom right). Collectively, they're known as Arp–Madore 2339-661, the moniker given to them when they were described in the Arp–Madore catalogue of peculiar galaxies, which was compiled in the 1970s and '80s.

A closer look, though, reveals that the two galaxies are actually three. Roughly two-thirds of the way along the blue upper arm of NGC 7733, you can see what appears to be a small clump of brown matter. Astronomers now believe that this is a third galaxy, provisionally now referred to as NGC 7733N. As the three galaxies are in very close proximity to one another, scientists say they will eventually merge to become one.

MORE **ONLINE**

Explore a gallery of these and more stunning space images



ESA/HUBBLE & NASA/J. DALCANTON/DARK ENERGY SURVEY/DOE/FNAL/NOIRLAB/NSF/AURA/ACKNOWLEDGEMENT: L. SHATZ

X-RAY: NASA/SAO/GSFC/M. CORCORAN ET AL/HST: NASA/ESA/STSCI/PROCESSING: NASA/CXC/SAO/L. FRATTARE/J. MAJOR/N. WOLK. DESI LEGACY IMAGING SURVEYS/LBNL/DOE & KPNO/CTIO/NOIRLAB/NSF/AURA/PROCESSING: T. A. RECTOR/M. ZAMANI/R. COLOMBARI & D. DE MARTIN, ESO/VPHAS+ TEAM, NASA./ESA AND J. LEE (STSI)/PROCESSING: GLADYS KOBER

△ Past echoes

HUBBLE SPACE TELESCOPE/ CHANDRA X-RAY OBSERVATORY, 26 SEPTEMBER 2023

This is the dual-star system Eta Carinae, encircled by the Homunculus Nebula. The vast clouds of gas that form the nebula were ejected by Eta Carinae in 'the Great Eruption' of the 1830s and '40s, during which the star became the brightest in the sky for nearly two decades.

◁ Shell company

VÍCTOR M BLANCO 4-METER TELESCOPE, 28 SEPTEMBER 2023

Seen here is NGC 3923, a shell galaxy 70 million lightyears away in the constellation Hydra. Shell galaxies are elliptical galaxies with an outer 'shell' of stars surrounding them, and are believed to be the result of galactic cannibalism – a larger galaxy gradually peeling stars away from a smaller galaxy to form the concentric bands.

△ Neighbouring nebulae

VLT SURVEY TELESCOPE, 2 OCTOBER 2023

This image features two different types of nebulae in the same shot. In the centre is bright diffusion nebula IC 1284, which is responsible for the surrounding region's rosy glow, while in the bottom right the reflection nebulae NGC 6589 and NGC 6590 appear blue.

Kind of blue ▷

HUBBLE SPACE TELESCOPE, 2 OCTOBER 2023

This swirling blue and gold beauty is intermediate spiral galaxy NGC 4654. The galaxy can be spotted (from the Northern Hemisphere, at least) with amateur-level telescopes in the constellation of Virgo, 55 million lightyears from Earth.

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The latest astronomy and space news, written by Ezzy Pearson

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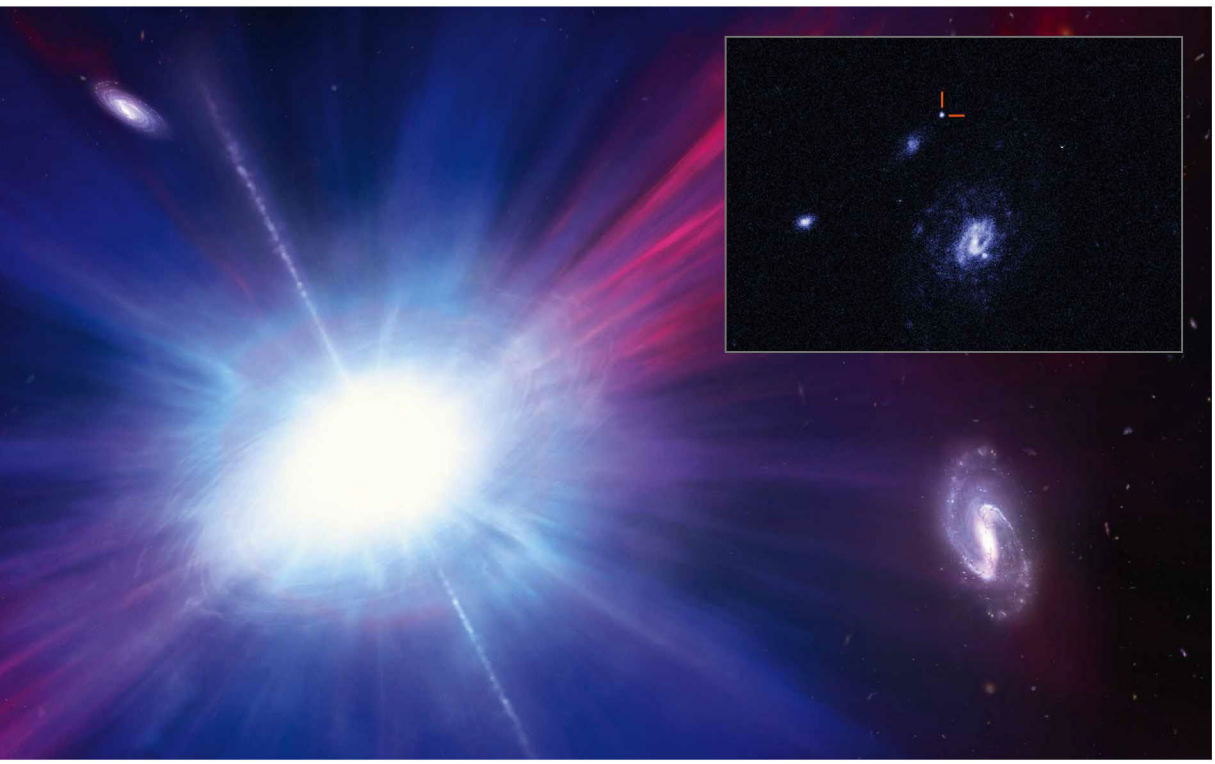


▲ An artist's impression of a Luminous Fast Blue Optical Transient (LFBOT) and (inset) the blue flash of 'the Finch'

NASA/ESA/NSF'S NOIRLAB/MARK GARLICK/MAHDI ZAMANI, NASA/ESA/STSCI/ASHLEY CHRIMES (ESA-ESTEC/RADBOUD UNIVERSITY)

Rare cosmic explosion deepens a mystery

One of the Universe's brightest outbursts seen in an unexpected location

Astronomers have spotted a rare burst of light that's thought to be one of the Universe's brightest phenomena, but it has only served to deepen the mystery of what causes these unusual events.

Luminous Fast Blue Optical Transients (LFBOTs) are very blue in colour and evolve rapidly, reaching their peak brightness and then fading away in a matter of days. Their short-lived nature makes them difficult to spot, and the first, dubbed 'the Cow', was only discovered in 2018.

Since then, they've been spotted at a rate of about one per year, mostly in the spiral arms of local galaxies. That led astronomers to believe they were unusual supernovae generated by huge but short-lived stars. This latest event, though – called AT2023fhn or 'the Finch', and first observed on 10 April 2023 – appears to have occurred not within a local galaxy, but in the space between two.

"The more we learn about LFBOTs, the more they surprise us," says European Space Agency research fellow Ashley Chrimes, who led the study. "We've now shown that LFBOTs can occur a long way from the centre of the nearest galaxy, and the location of the Finch is not what we expect for any kind of supernova."

There are other possible explanations. It could be that the event is a collision between two neutron stars, where one is highly magnetised and so amplifies the explosion. Alternatively, LFBOTs could be stars being torn apart by intermediate black holes with a mass between 100 and 1,000 times that of the Sun. These are thought to lie in globular clusters, which would evade Hubble's view but could be found in future observations by the James Webb Space Telescope.

"The discovery poses many more questions than it answers," says Chrimes. "More work is needed to figure out which of the many possible explanations is the right one."

hubblesite.org

Comment

by Chris Lintott

Rather than the never-changing cosmos that centuries of astronomers thought they were exploring, modern surveys show a surprising variety of things that go bang in the night.

The Vera C Rubin Observatory will soon start scanning the whole sky every three nights with a 8.4-metre telescope. In its first tranche of data will be more supernovae than we've recorded in human history, all sorts of exotic objects and – hopefully – plenty of LFBOTs.

Almost all the mechanisms suggested for LFBOTs, from colliding black holes to supernovae, must happen out in the Universe, and they should show up in Rubin's data. Exciting times, whatever the Finch turns out to be.

Chris Lintott co-presents *The Sky at Night*

▲ **The UK's first ESA astronaut, Tim Peake, announced his retirement from ESA this year but is being mooted to command the mission**

Plans for an all-UK space mission set in motion

Four British astronauts could soon be heading into orbit

An all-UK space mission could soon be heading into orbit with a crew of four British astronauts – and it's rumoured that veteran UK astronaut Tim Peake could be chosen to lead the mission.

US spaceflight company Axiom Space has signed a memorandum with the UK Space Agency to begin arrangements for the mission, which would conduct experiments and outreach activities over a two-week stay in orbit. The £200m price tag would be funded by commercial partners, not the UK tax payer.

"We want to put the UK at the forefront of the global race for commercial space investment, continue to support scientists and engineers to test new technologies and carry out important research and, ultimately, bring the benefits back to people and businesses across the country," says George Freeman, Minister of State at the Department for Science, Innovation and Technology.

Few solid details about the mission have been announced so far, though previous Axiom flights have visited the International Space Station. If this were the case, then NASA would insist on a veteran astronaut heading up the crew.

Currently, that would mean former ESA astronaut Tim Peake, who flew to the station in 2015. Several news outlets reported that Peake would command the mission during the announcement, but this was still to be officially confirmed as of the time of writing. Other potential crew members include Rosemary Coogan and John McFall, who are currently training as ESA astronauts, and reserve astronaut Meganne Christian.

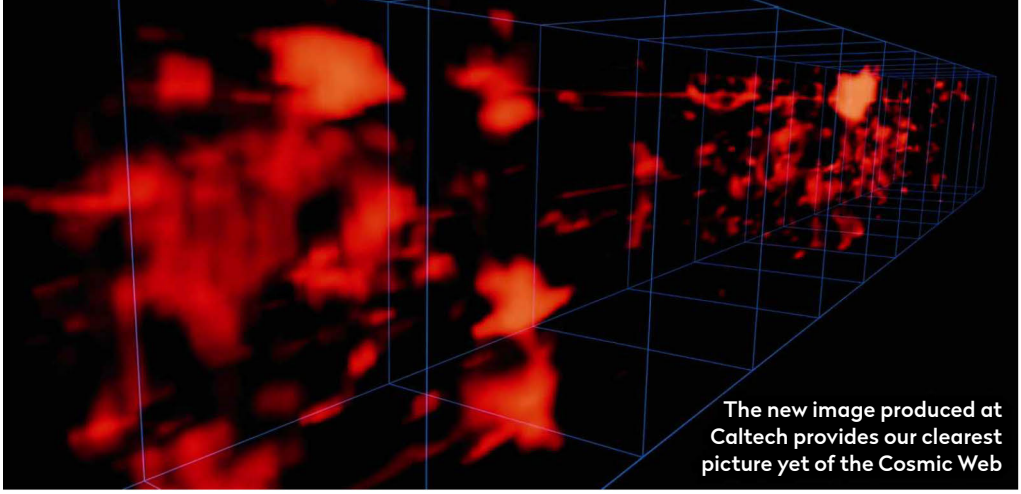
The UK has a thriving space industry already, and one of the goals of the proposed mission is to highlight and encourage this area even further. The UK Space Agency has sent out a call to UK universities, research and educational institutions for proposals for projects that can run alongisde the mission to highlight work being done in space in the UK.

"There are several hurdles to overcome, the financial model needs to be secured, crew selection and training. And NASA needs to approve the mission and they need to identify a slot, if it is to go to the International Space Station," said Peake, speaking on BBC Radio 4's *Today* programme on 25 October.

"It's early days and there are several steps to go through, but it is fantastic that we have started the ball rolling with these exploratory discussions."

www.gov.uk/government/organisations/uk-space-agency

ESA/NASA, CALTECH/R. HURT (IPAC), NASA/ERIKA BLUMENFELD & JOSEPH AEBERSOLD, AMAZON



The new image produced at Caltech provides our clearest picture yet of the Cosmic Web

Cosmic Web mapped for the first time

Hidden filaments of gas come out of the shadows

The interconnected series of gas filaments that stretches between galaxies, the Cosmic Web, has been mapped for the first time.

"The Cosmic Web delineates the architecture of our Universe," says Christopher Martin from the California Institute of Technology, who led the study. "It's where most of the normal, or baryonic, matter in our Galaxy resides, and directly traces the location of dark matter."

Until now, astronomers have only been able to glimpse the gas within the Web when it is being illuminated by a bright quasar, meaning the thin filaments between galaxies have remained in the dark.

To trace out these previously invisible pathways, Martin's team used the Keck Observatory in Hawaii to pick out a specific wavelength of light created by hydrogen gas within the streams called the Lyman alpha line. The further this light has travelled, the more it will have been redshifted, giving an indication of how far away it is.

"We take spectra for every point in an image at a range of wavelengths, and the wavelengths translate to distance," explains Martin. "We are basically creating a 3D map of the Cosmic Web."

www.caltech.edu

The sample collection module from OSIRIS-REx recently returned to Earth

Bennu rich in water and carbon

The sample brought back from asteroid Bennu by NASA's OSIRIS-REx mission is rich in water and carbon, according to initial studies. On Earth, carbon and water form the building blocks of life. As Bennu dates from around 10 million years after the Solar System formed, the find could give vital insights into how these life-giving chemicals arrived on Earth.

The sample was returned to Earth on 24 September 2023 and was transported to the Johnson Space Center to be opened. The science team there performed an initial investigation, scanning the interior of one of the grains and conducting a basic chemical analysis, which revealed the water and carbon. Once this primary assessment is complete, the sample is to be distributed to over 200 scientists around the world for detailed analysis.

"Our labs were ready for whatever Bennu had in store for us," says Vanessa Wyche, director at NASA's Johnson Space Center. "We've had scientists and engineers working side by side for years to develop specialised gloveboxes and tools to keep the asteroid material pristine and to curate the samples, so that researchers now and decades from now can study this precious gift from the cosmos."

www.nasa.gov

NEWS IN BRIEF

First Project Kuiper satellites launch

Amazon launched the first two prototype satellites of its Project Kuiper mega-constellation on 6 October 2023. Over the next six years the company aims to launch more than 3,200 of the satellites, which will be used to enable broadband access around the world.

Northern Sun spottier

September was the second month in a row in which twice the number of sunspots were seen in the Sun's northern hemisphere than its southern one. The Sun is currently heading towards the maximum of its 11-year solar cycle, which is typically the time when one of the hemispheres becomes dominant in this way.

Ancient cosmic blast

Astronomers using ESO's Very Large Telescope have spotted the most distant Fast Radio Burst ever seen. FRB 20220610A is so far away its light has taken eight billion years to reach us. These events are huge blasts of radio waves that last less than a millisecond but release the same amount of energy as our Sun does in 30 years.

NEWS IN BRIEF

NASA's Psyche mission gets under way

NASA's Psyche mission successfully launched from Florida's Kennedy Space Center at 14:19 GMT on 13 October. The mission will now spend the next six years travelling 3.6 billion kilometres to enter into orbit around the metal-rich asteroid of the same name.

India dreams big

The Indian Space Research Organisation has announced an ambitious set of goals for its human spaceflight programme. In addition to the first crewed flight of its Gaganyaan spacecraft, scheduled for 2025, the agency also aims to set up its own space station by 2035 and land the first Indian on the Moon by 2040.

Growing up in the middle

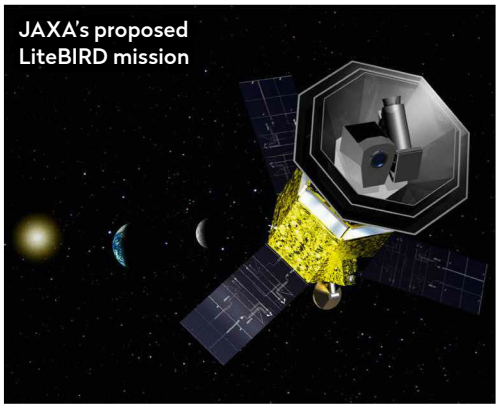
Intermediate black holes with masses several hundred times that of the Sun could form in the dense environment of stellar clusters, a new set of computer simulations has shown. Astronomers already understand how stellar-mass and supermassive black holes form, but have long been uncertain about those with masses in between.

NASA/JPL-CALTECH, LITEBIRD CONSORTIUM, ESA/DLR/FU BERLIN

BULLETIN

UK helps build new CMB observatory

British engineers will design and build key aspects of the mission



JAXA's proposed LiteBIRD mission

The UK is to play a key role in LiteBIRD, a new Japanese-led mission to study the cosmic microwave background radiation (CMB).

The mission will analyse the light left over from the Big Bang, with the primary goal of hunting for the primordial gravitational waves that shaped the CMB during its formation. The UK Space Agency plans on investing a total of £17m in the mission, which is currently due to launch by 2030. This funding will go to UK scientists designing elements of the science instruments, as well as to a team at Cardiff University who are designing and producing the telescope's lenses and filters.

"We expect LiteBIRD to be a game-changer for our understanding of cosmology, putting our best theories to the test as to what happened at the start of the Universe," says Dr Paul Bate, chief executive of the UK Space Agency.

"It's incredibly exciting for the UK to be at the forefront of this mission, working together with international partners to push the boundaries of space science and answer some of humanity's biggest questions."

global.jaxa.jp

▶ Turn to page 36 to read our CMB feature

Chaos could hide signs of Martian life

A chaotic and broken region of Mars's terrain could provide an opportunity to investigate a rich vein of potential biomarkers on the Martian surface, a new study has revealed. The site has been put forward as the location of a future landing mission.

Liquid water once flowed across Mars, meaning it could potentially have been habitable. In order to search for signs of past life, geologists seek out areas that could be rich with 'biomolecules' – the chemicals that form the building blocks of life. One place such chemicals would have collected is in underground aquifers, which would occasionally flood the planet's surface.

"As the water was released to the surface and ponded, the water went away leaving behind [layers] of sediments and potentially high concentrations of biomolecules," says Alexis Rodriguez from the Planetary Science Institute, who led the study. "These sediments might harbour evidence of life from that or subsequent periods."

However, such rocks would have been created 3.4 billion years ago and so would be deep underground and inaccessible to any landing mission wishing to investigate them. One potential window into these layers, however, is in a region of collapsed rock formations, or chaos terrain, known as Hydroates Chaos. Here, the jumble of plateaus and valleys exposes the lower rock layers, allowing them to be investigated.

▲ Hydroates Chaos, as imaged by Mars Express in 2004, could provide clues of past life on Mars

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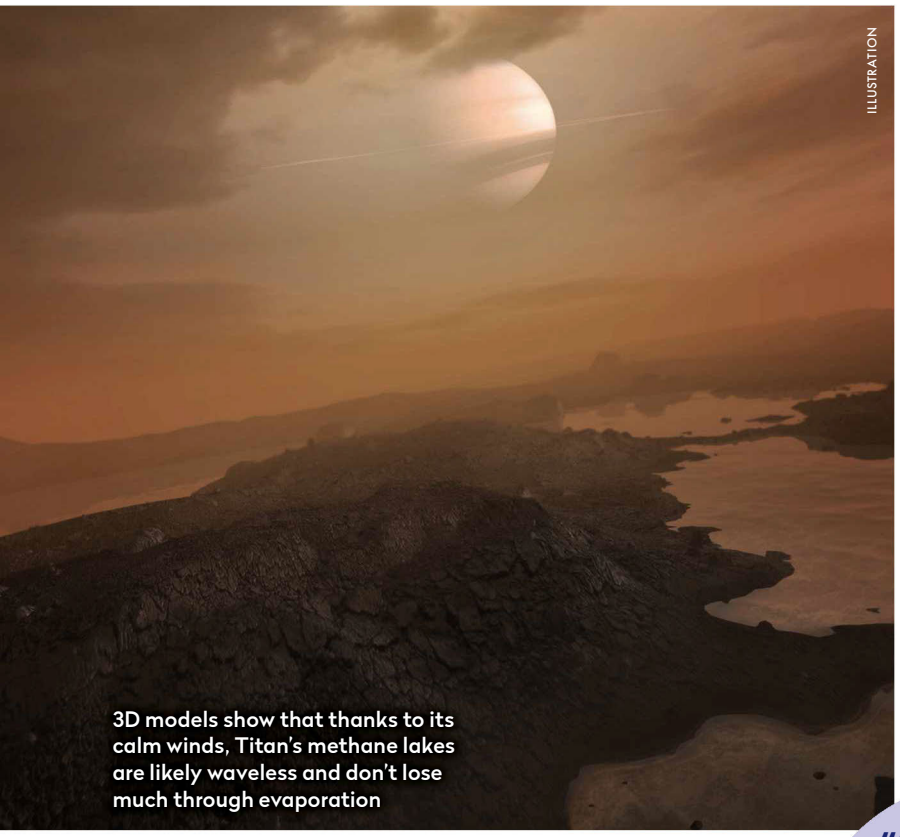


ILLUSTRATION

3D models show that thanks to its calm winds, Titan's methane lakes are likely waveless and don't lose much through evaporation

No call for sea legs on Titan

Expect to find gentle breezes and calm seas on Saturn's largest moon

One of the most stunning discoveries delivered by NASA's Cassini probe to the Saturn system was that its moon Titan hosts a number of lakes (confirming evidence from the Hubble Space Telescope). Titan is a giant moon with a thick atmosphere, and had long been suspected to offer appropriate conditions for bodies of liquid methane and ethane on its surface. The largest of these, Cassini found, range from hundreds of kilometres to over 1,100km in length, and so are referred to as seas. The probe also spotted hundreds of other smaller lakes, ranging from just a few kilometres to 240km. Some of these bodies exhibit intricate shorelines, and many cluster together near the north pole: a Titanic Lake District.

Seas and large lakes on Earth affect the local wind conditions. They take longer than the land to warm up and cool down on a day-to-night cycle, as well as over the seasons, and evaporation from their surface also affects heat transfer. The temperature differentials created by these factors generate either onshore or offshore winds. So a natural question arises: how do Titan's large methane lakes affect the moon's winds? Previous studies have explored this with 2D models, but now Audrey Chatain at the Department of Space Studies, Southwest Research Institute (SwRI) in Boulder, Colorado, and her colleagues, have improved on these efforts by simulating atmospheric movements around Titan's lakes in all three dimensions.

Chatain's models show that although the conditions on Titan and Earth are extremely different, the breezes formed around Titan's lakes are actually broadly similar to those on Earth in terms of the extent of the winds above the surface and how far inland they penetrate. Her team also found that these surface winds are strongest around the edges of the largest seas, and for lakes nearer the equator during summer, as would have been expected. But even in these situations, Chatain calculates that these lake winds never exceed a very gentle breeze of 0.2m/s – far slower than analogous lake winds on Earth of around 5m/s. She notes that even these strongest lake breezes on Titan would not be enough to create wind-driven waves on the moon's seas.

"Although Titan and Earth are extremely different, breezes around Titan's lakes are actually broadly similar to those on Earth"

Chatain's team also determined an evaporation rate from Titan's lakes of around 6cm per Earth year, which is far lower than the values of 20–50cm suggested by previous, simpler 2D models.

Another new result from these 3D models is the formation of a stable layer of cold but moist air in the first few metres above the lakes. Chatain calculates that under these conditions the evaporating methane could reach saturation and condensation: Titanic sea fogs.

Overall, the winds on Titan are much weaker than those on Earth, so although far-future explorers may experience the singular pleasure of a boat ride on liquid hydrocarbon seas, they'd struggle to go sailing.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *The Impact of Lake Shape and Size on Lake Breezes and Air–Lake Exchanges on Titan* by Audrey Chatain et al.
Read it online at: arxiv.org/abs/2309.07042

MARK GARLICK/SCIENCE PHOTO LIBRARY/ISTOCK/GETTY IMAGES, NASA/GSFC/S. SNOWDEN ET AL/NOAO/AURA/NSF/MIDDLEBURY COLLEGE/F.WINKLER ET AL

Swirling supernova's secret sibling

A companion could be responsible for Puppis A's overlapping rings

Prof Chris Lintott is an astrophysicist and co-presenter on *The Sky at Night*

The Puppis A supernova remnant is one of the most intriguing and interesting objects in the sky. Slightly overlooked because it's partly hidden behind the nearer Vela remnant, it is the result of an explosion whose light reached Earth about 3,700 years ago. Since then, the bubble of shocked gas has expanded to a diameter of about 100 lightyears, at the centre of which is one of the brightest X-ray sources in the entire sky.

Of particular interest is what lies within the main body of the remnant. In images taken in both X-ray and visible light, there is a set of nested and overlapping rings. Named 'The Swirl' by its discoverer Frank Winkler (making it the object in the sky which most sounds like something a *Star Trek* captain would encounter), it was originally thought to be the signature of a second supernova taking place within the remnant of the first.

This month's paper, which takes a close look at the Swirl, comes to a different conclusion. The authors argue that the remnant is actually being sculpted by the presence of a second star, a companion to the supernova progenitor, whose influence on the initial explosion is being revealed all these millennia later.

The tool of choice is an integral field spectrograph, mounted on the relatively modest 2.3-metre telescope at Siding Spring Observatory in Warrumbungle National Park, New South Wales, Australia. These instruments, which are slowly revolutionising professional astronomy, give not only an image of the target, but also a spectrum for each pixel within a grid. This gives the team two for the price of one – they can study the image to get a sense of the structure of the Swirl, while the spectra tell us how its movements and composition change across the object.

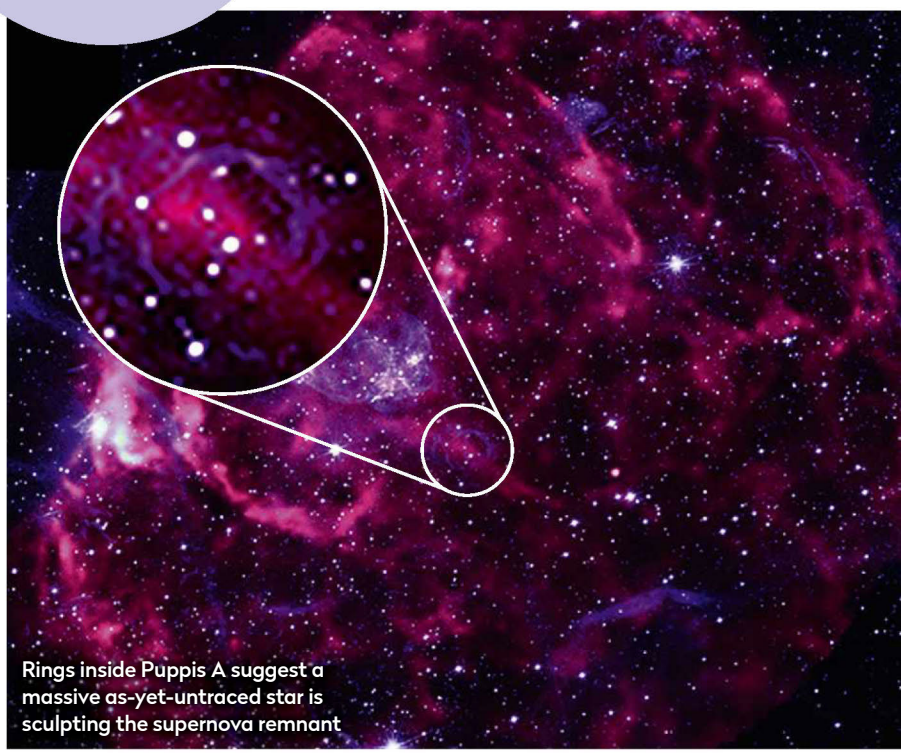
With data in hand, they consider whether the Swirl could be material spewed into space by a wind from the progenitor before it went supernova. If this hypothesis is true, we'd expect the Swirl's rings to be uniform, with no changes in composition from place to place. Instead, different rings are made of different things: the outermost one is nitrogen-rich, while inner components show oxygen and sulphur too.

As massive stars reach the end of their lives, they end up with an onion-like interior, their 'burning' of nuclear fuel producing layers of different heavy elements. The pattern seen in the Swirl corresponds to being made up of a series of these layers – though the pattern does break down slightly in the innermost components.

But why do we see a series of rings? This is where the presence of a companion comes in. If such a star exists, it would have got in the way of material flowing outwards during the supernova, producing a funnel shape, which we see as the Swirl.

"If such a star exists, it would have got in the way of material flowing outwards during the supernova, producing a funnel shape."

It's an elegant explanation, but could the companion star have survived? Recent searches using data from the European Space Agency's Gaia satellite have found nothing, though the authors suggest a broader search might be needed. As ever, understanding the complexity of these fascinating objects requires more observations.



Rings inside Puppis A suggest a massive as-yet-untraced star is sculpting the supernova remnant

Chris Lintott was reading... *The Peculiar Ejecta Rings in the O-Rich Supernova Remnant Puppis A: Evidence of a Binary Interaction?* by Parviz Ghavamian et al. **Read it online at: arxiv.org/abs/2310.00661**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

▲ **Radio partners Ince and Cox made a joint TV appearance on *The Sky at Night***

Host of science podcast *The Infinite Monkey Cage* **Robin Ince** joined his co-host Brian Cox on the November episode of *The Sky at Night*

The speed of light enchants the sky. It adds another story to the night. Curiosity, whether scientific or artistic, adds dimensions to the world we walk through.

One of the objectives of *The Infinite Monkey Cage*, the radio series I have presented with Brian Cox for 14 years, is to excite as well as to inform. We don't just want people leaving an episode with more 'facts', we want them to depart with a new excitement and emboldened fascination. I have always felt this about *The Sky at Night*, too: the most important concern of each episode is to encourage you to spend more time looking upwards and outwards, beyond our atmosphere and back in time.

I am not an astronomer, but I spend a lot of time looking up after dusk, often with the naked eye – 'lazy astronomy' as some call it – and sometimes through my telescope. I can't name all the constellations, and sometimes I mistake Venus for Jupiter and vice versa. The first and most important thing for me is connection: winning the quiz of naming what is where comes far further down the line. Standing on a deserted street in the Outer Hebrides some time ago, I saw a shooting star. There was no need to wish on it, because the wish had been fulfilled already. It was a transcendent moment where I was connected with the Universe. At times like this, knowledge such as what comet might have given rise to its origin comes in second for me.

We live in a world where people love pointing out when you are wrong. People run scared of showing their curiosity for fear they will say something wrong and be socially shamed for it. Anxiety can be a cause of ignorance. We learn by asking questions, not by merely parroting answers. If we don't reveal what we don't know then we'll never learn.

As an amateur 'amateur astronomer', each new piece of information illuminates the illuminations. Which got me wondering: when did I first know about the speed of light?

Sure, there will have been plenty of science-fiction pieces where the captain will have made stern demands to accelerate to lightspeed, but did my junior brain really understand that the light around

BBC X 2, SIPA US/ALAMY STOCK PHOTO, NASA/JPL

Robin Ince is a comedian, writer, broadcaster and populariser of scientific ideas

me was not a motionless glow, but something that was moving towards me?

One night, looking at the sky, I felt the light hit my eye. Sure, it was psychosomatic, but it was real enough for me to reconsider the stars.

I thought about the distance the starlight had travelled: parochial by comparison with the size of the Universe, but immense when considering how far human beings can currently imagine travelling.

I thought of how those photons of light had come into being during a nuclear reaction – as hydrogen became helium in the heart of a star and light was created. I was the lucky recipient of some of it, when so much of that light is doomed to collide with matter that can neither delight in its beauty nor question its existence.

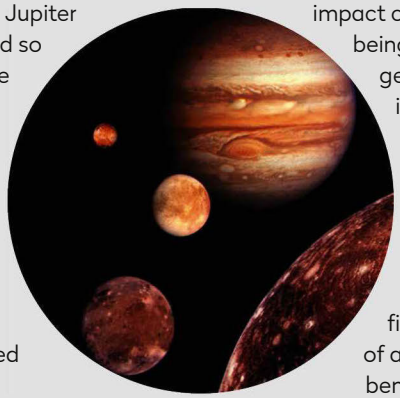
Talking to an astronomer in a back garden – I think it was *The Sky at Night*'s Chris Lintott – he told me of the photons he pitied. The photons that were on a direct course to the astronomer's retina, but just as the meeting was about to occur, the astronomer noticed that their shoelace was undone and then bent down as the photon sped on into the moss and heather, unnoticed by the aware.

One day I'll be more sure of my Venus from my Jupiter, but for now, I am happy to just keep looking.

Looking back: The Sky at Night

21 December 1986

On 21 December 1986, Jupiter was high in the sky and so Patrick Moore took the opportunity for a better look at the planet's four largest moons: Io, Europa, Ganymede and Callisto, known collectively as the Galilean moons, as they were first observed by Galileo in 1610.



▲ **Jupiter's four largest moons were first observed by Galileo in 1610**

By 1986, there had been only a handful of brief opportunities for a closer look at the moons. In the early 1970s, Pioneer 10 and 11 returned a few blurry images each. But just a few years later in 1979, the moons were captured in glorious detail by Voyager 1 and 2.

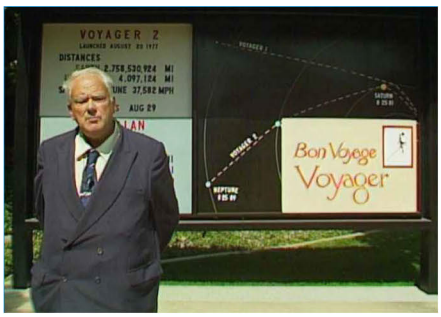
They revealed that Io was painted with yellows and oranges, and that its craters are not from meteor impacts but recent volcanic activity. Meanwhile, smooth, white Europa has very few impact craters, suggesting it's being refreshed by active geology. Its icy surface is criss-crossed by red veins, highlighting what appear to be fractures. The largest moon, Ganymede, was found to have a rocking magnetic field – a potential sign of an ocean hidden beneath its surface. Finally, the spacecraft imaged a 'bulls-eye' formation at Callisto, believed to be caused by shockwaves from an ancient meteor impact.

Since 1986, several missions to the gas giant have stopped off to look at these moons, but now the satellites are set to take centre stage. Over the next decade, ESA's JUICE and NASA's Europa Clipper are due to arrive at Jupiter, both of them dedicated to studying these mysterious icy worlds.

Explore *The Sky at Night*'s archive

The Sky at Night is taking a break this month, with the show due to return in 2024. In the meantime, explore the *Sky at Night* TV archive via the BBC iPlayer, where you'll find episodes from the last series, plus classic episodes in which Patrick Moore learns about the Voyager spacecraft, meets astronomer Clyde Tombaugh and reviews missions to Mars and Saturn. The *Sky at Night* website also includes plenty of stargazing advice and useful downloads to keep you busy until the TV show returns next year.

Visit www.bbc.co.uk/skyatnight for more information



▲ **In a 1989 episode of *The Sky at Night*, Patrick Moore finds out what Voyager 2 has discovered at Neptune**

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

A journey into wonder

I have always had a passing interest in the night sky, but never took it any further until I read an equipment review in the June 2020 issue of *Sky at Night Magazine* and then other 'first telescope' info and advice from your online resources and articles. Even after all this time, I'm still very much a novice with all things astronomical, but I'm slowly learning to find my way around the night sky with the help of your Binocular Tours, Star of the Month and Moonwatch sections each month.

One of my most memorable first observations was the Pleiades star cluster – it still wows me to this day! – but my very first was the Moon. To actually see such detail on the lunar surface in real time never fails to amaze me. Trawling through some old photos the other day, I found this one, which I thought I'd share. It's one of the first pictures I took, back in December 2021, with my mobile phone and eyepiece adaptor setup. It's a bit of a faff to get the phone lens aligned with the telescope eyepiece, but not bad for a first effort. Thank you for an excellent magazine. Keep up the good work!

Gary Bywater, Oldham

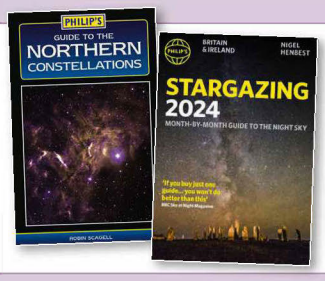
Thanks for the kind words, Gary! It's a real pleasure to hear the magazine is inspiring you to get out under the night sky – ***Ed.***

▲ After his early Moon shots, Gary has continued to embrace his new hobby

This month's top prize: two Philip's titles

The 'Message of the Month' writer will receive a bundle of two top titles courtesy of astronomy publisher Philip's: Nigel Henbest's *Stargazing 2024* and Robin Scagell's *Guide to the Northern Constellations*

Winner's details will be passed on to Octopus Publishing to fulfil the prize



Instagram

astro_alvarado • 14 October
Cloudy Annular Eclipse. Three chances against clouds, three accurate shots. Gear: Canon 700D 200mm and Baader solar filter black polymer #2023 #annulareclipse #sun #solar @bbcskyatnightmag

Mined over matter

I'm writing to you after reading your article 'Metal-rich asteroids like 16 Psyche could be mined for their resources' (**www.skyatnightmagazine.com**). As a petroleum and mining student, I'm taught the basics of mining and I'm also interested in astronomy. From there I became interested in asteroid mining. I think asteroids *should* be mined. The resources of minerals and metals on Earth are finite and non-renewable, and to meet our future demand we need to work for new resources. Asteroids are a vast source of iron, nickel, cobalt, platinum, titanium and more. But it is not a quick and easy task to do mining on an asteroid; even collecting samples to return to Earth takes a long time – Hyabusa2 took six years, OSIRIS-REx took seven years. So we need to start developing asteroid mining now and work on it as a long-term project, in order that when the reserves of metals on Earth are at an end, we will have a new source available.

Jannatul Karimoon, Chittagong University, Bangladesh

Value judgement

It's said that with the astronomical amount spent on space research and travel, we should be able to extract useful substances from asteroids, the Moon and elsewhere. But consider this: whenever the supply of a valuable substance greatly increases, its market value decreases!

Joe Silvia, Lakeville, Massachusetts, USA

It's not a meteor, so what rotating object did Mike capture?

Curious trails

I was attempting to image some of the Draconids on Sunday 8 October. I failed to capture a single meteor, but half a dozen of the 700-odd frames had strange-looking satellite trails which appear to suggest the satellite is rotating. Each exposure was 10 seconds, so there would be about one rotation per second or so. Also, unlike 'normal' trails, they are very dim in the frames either side. Do you have any idea what kind of objects these are?

Mike Cuffe, via email

Inspiring stuff

I was interested to read the Looking Back section in 'Inside the Sky at Night' (October issue), which was remembering the close approach of the Giotto probe to comet Halley in 1986. I remember sitting up through the entire special episode of *The Sky at Night* on Giotto's close approach to Halley, presented by Sir Patrick. It was watching that programme that kickstarted my interest in astronomy – and 37 years later, the bug is still biting.

Paul Byrne, Dublin

On the Spot

I enjoyed reading the feature by Giles Sparrow about Jupiter's belts ('Solving the mystery of Jupiter's shifting belts', November issue) and saw from the illustration of the Great Red Spot that cool gas sinks down its central sub-vortex. In hurricanes on Earth, hot air rises up through their ▶

ON FACEBOOK

We asked: What are your top tips for getting kids and young astronomers interested in observing the night sky?

Brandon Booysen I take out my telescope and get them to look at the Moon and stars. Tell them indigenous astronomy stories about our Universe.

Clive Lewis The DWARF II smart telescope is a good option.

Philip Grombliniak The best way to inspire them is to get your telescope out, get all the kids on the block and show them the stars, the Moon and the planets on a hot summer night. Teach all the children. Once they see these objects through a telescope it'll stick with them forever. Every night look up, not down. Teach them the stars, make songs, make videos. What they learn they'll pass on to their children.

Adrian Pink Always start with close-ups of the Moon.

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With **Steve Richards**

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I'm looking to do more astrophotography trips. Can you recommend a good travel mount I can use with my DSLR camera?

STEVE PENNY

STEVE RICHARDS

▲ The Vixen Polarie offers a compact way to track the stars

Mounts for use purely with DSLRs have become popular in recent years as astronomers discover the delights of widefield deep-sky astrophotography. While many don't have Go-To or even declination motors, they're ultra-portable yet capable of the excellent right-ascension tracking required for long-exposure imaging.

Popular mounts include the Vixen Polarie Star Tracker, Sky-Watcher Star Adventurer 2i WiFi and iOptron's SkyGuider Pro. If Go-To functionality is a must, the Sky-Watcher Star Adventurer GTi and iOptron SkyHunter Portable EQ/AZ GOTO mounts should be on your shortlist.

More recently, strain wave gear drives, commonly known as Harmonic Drives, have been incorporated into portable mounts as they provide high torque with low backlash in a compact package. Although significantly more expensive than traditional mounts, you may wish to explore both the Crux 140 Traveller Harmonic Drive and the Rainbow Astro RST-135E mounts, which also have Go-To functionality. You can find reviews of many of these at **www.skyatnightmagazine.com**.

Steve's top tip

What is field curvature?

The curved optical surfaces used in telescopes to bend the light from celestial objects result in a curved focal plane. This means that objects at the centre of the field of view are in focus but those further out, known as being 'off-axis', will be slightly out of focus. Although not a big problem for observers, as the eye is very good at compensating for this aberration, it can be significant for deep-sky astrophotographers. The flat surface of a camera's sensor is unforgiving and photographic images will clearly show off-axis stars as being out of focus and elongated, unless corrected by additional optics.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

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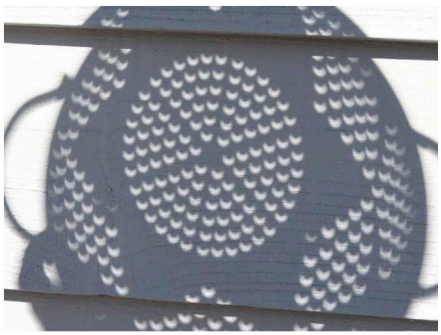
Tweet

StrollingShuttereyes
@strollingshutte • 14 Oct
Autumn Eclipse, 2023.
Despite my location in NW Wisconsin, overcast skies and breezy conditions, a brief moment availed itself and one of a handful of images of the #SolarEclipse2023 were captured! @apod @yourtake @NatGeo @skyatnightmag

▶ centre, which prompted me to wonder if there is any significance in the difference. I was also interested to read that gravitational contraction allows Jupiter to emit twice as much heat as it gets from the Sun. My question is: if Jupiter ignited and became a star, what effect would that have on Earth?
Thomas Jones, via email

The hole works

Sadly, we were not in the path of full annularity for the solar eclipse on 14 October. I could have driven to it, but I stayed home. The skies were forecast to be clear and since I live higher than 2,830m there is rarely any light pollution. As expected, the skies did get darker at maximum coverage. I had created a single pinhole camera, but it wasn't very good, so my wife came up with the idea to use kitchen colanders. I saw the 1994 annular eclipse from Lake George, New York, when I used my baseball hat, which had five holes in it, to project an image!
Donald Samuels, Silverthorne, Colorado, USA



▲ Donald projected the eclipse through a colander – a great way to safely see it

SOCIETY IN FOCUS

Chesterfield Astronomical Society was founded by Horace Barnett, and our headquarters, the Barnett Observatory, is named after him. It was officially opened on 21 April 1960 by the Astronomer Royal at the time, Sir Richard van der Riet Woolley. Later we were visited by Sir Patrick Moore.

Building began in 1957 and took three years to complete. The 18-inch mirror, housed in a three-metre tube in the dome, is made of glass and was hand-ground by Val Warburton, a friend of Barnett's. It's still in use today. The telescope is motor-driven but is not a Go-To, so we locate objects by eye or with setting circles. It can be used for imaging deep-sky objects, as well as the Moon.

We open on Fridays at 8pm all year round. It's a social evening for members as well as an astronomy event. We have talks from speakers in person or online.

We love having groups of all ages come to visit us. One of our members gives an age-appropriate talk in our lecture room and, weather permitting, we observe through our main telescope. We also go out to visit other venues, sharing our enthusiasm for astronomy and the beauty of the night sky.

▲ Young astronomers from Belarus during a talk at Barnett Observatory in 2019

Formerly we hosted regular annual visits from a group of young astronomers from Belarus, who came to learn about the observatory. We hope to welcome them again to Chesterfield in the future. All this from a spare patch of land and a man with a vision!
Sue Silver, committee member, CAS
▶ chesterfield-observatory.co.uk

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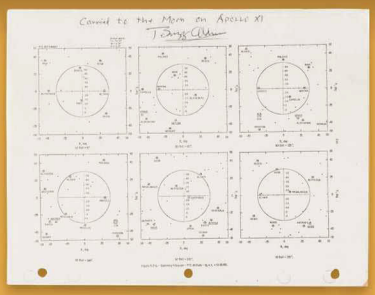
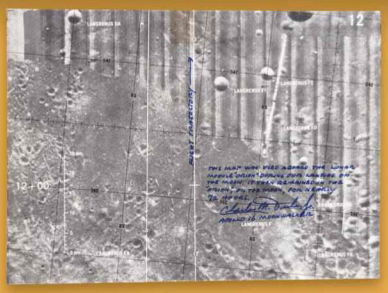


Apollo 11 Flown *Flight Plan* "Scanning Telescope" Page, Originally from the Personal Collection of Mission Lunar Module Pilot Buzz Aldrin, Signed and Certified, with Signed Extensive Letter of Authenticity.



Apollo 16 Lunar Module Flown Lunar Orbit Monitor Chart, Directly from the Personal Collection of Charlie Duke.

Apollo 11 Lunar Module Flown Section of the Wright Flyer's Wing Fabric, Position #162, Flown as Part of the First Successful Powered Controlled Flight in History at Kitty Hawk in 1903 as well as the First Manned Lunar Landing in 1969.

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HERITAGE AUCTIONS

We pick the best live and virtual astronomy events and resources this month

WHAT'S ON

ROYAL OBSERVATORY GREENWICH, MIKE HAWTIN

Chinese Astronomy

Royal Observatory, Greenwich, London, 16 December, 10:30am

This live planetarium show takes a look at the night sky as seen from China, and at some of the subjects that have fascinated Chinese astronomers over the centuries, including the Sun, Moon, stars and space exploration. £10 for adults, £5 for children. **www.rmg.co.uk**

Solutions to Space Debris

Bath Royal Literary and Scientific Institution, Queen's Square, Bath and via Zoom, 1 December, 7:30pm

Remote sensing expert Dr Philippe Blondel presents a talk on space debris and how to avoid it. Tickets cost £6 (£3 for members and students) and the event can also be attended via Zoom. **herschelsociety.org.uk**

The Sun: An Introduction to Solar Imaging

Wulfruna Street, Wolverhampton, 4 December, 7:30pm

Wolverhampton Astronomical Society welcomes solar imager Gary Palmer of the Royal Astronomical Society and the British Astronomical Association, for a guide to capturing images of the Sun. Free for members, non-members £2. **www.wolvas.org.uk**

The Science of Palomar Observatory, 1936 to the Present

Astronomical Society of Edinburgh, online, 15 December, 7:30pm

In this free online lecture, Steve Flanders from Caltech's Palomar Observatory in southern California looks at some of the most important research conducted there over the past 87 years, including efforts to calibrate cosmic expansion. **www.astronomyedinburgh.org**

Skylab: Apollo's Space Station

Royal College Building, University of Strathclyde, 21 December, 7:30pm

The Astronomical Society of Glasgow hosts regular free public lectures and this month's speaker is Robert Law from Dundee's Mills Observatory. His talk looks at NASA's short-lived 1970s Mir rival and International Space Station precursor, Skylab. **www.theasg.org.uk**

Black Hole Jets

Queen's Buildings, Cardiff University, 21 December, 7:30pm

Astrophysicist and X-ray astronomer Professor Diana Worrall presents an overview of her research into the jets of radiation that emerge from black holes. Free for members; non-members please email in advance. **www.cardiff-astronomical-society.co.uk**

PICK OF THE MONTH

▲ The dark-adaptation-friendly Hub at Sutton Bank – ideal for some meteor spotting

See the Geminid meteor shower's peak

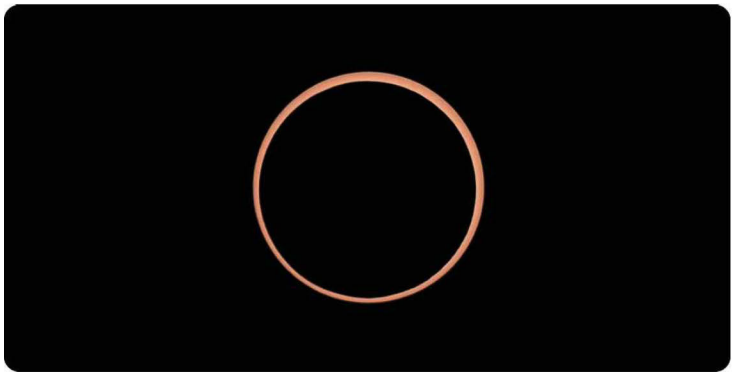
Sutton Bank Star Hub, Thirsk, North Yorkshire, 13 December, 7pm

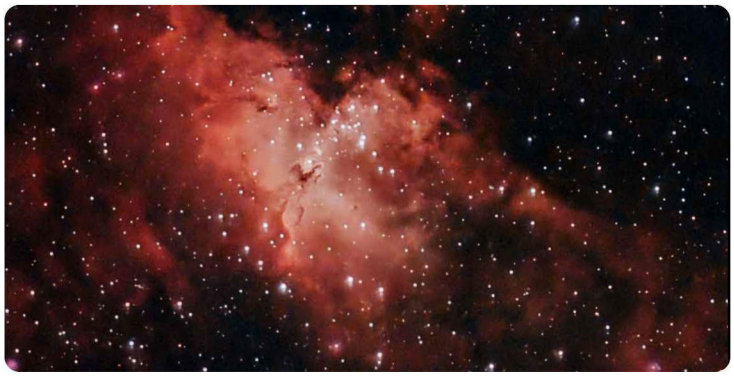
Renowned dark-skies campaigner and astronomy educator Richard Darn (of Dark Skies UK) hosts a public observing session, timed to coincide with the peak of the Geminid meteor shower, in the plush surroundings of Sutton Bank Star Hub. Located in Sutton Bank National Park, the hub was purpose-built for astronomers in 2021 and features a warm, comfortable indoor area for talks and presentations – in this case, a planetarium show in the event of bad weather – as well as an outdoor viewing area with room to set up telescopes. Tickets are £20, £15 for under 16s. Early booking is advised as numbers are strictly limited. **bit.ly/3FhuQy0**

Discover the Universe with

DwarfLab's DWARF II Smart Telescope

Unlock the secrets of the universe, capture the elusive beauty of wildlife, and witness breathtaking panoramas with the DWARF II Smart Telescope by DwarfLab. Compact yet powerful, this device is designed for those who crave adventure and exploration without the burden of heavy equipment or complex setups.





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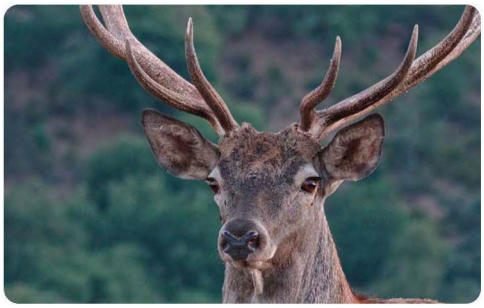

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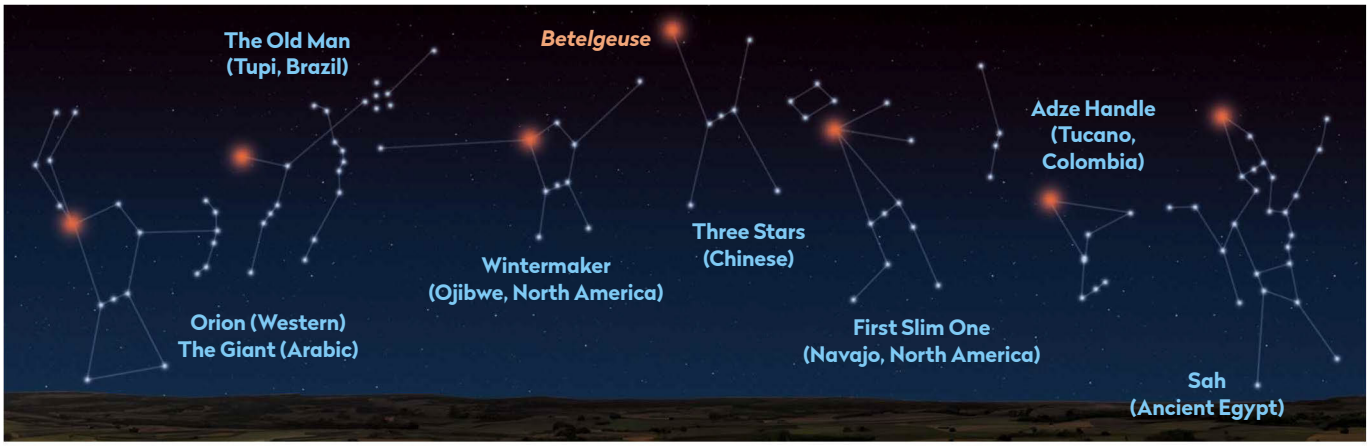
FIELD OF VIEW

Same stars, different stories

Maggie Aderin-Pocock considers how other cultures interpret the night sky



▲ **The constellation we in the West call Orion is a star pattern that's represented in remarkably different ways by other cultures globally**

PAUL WOOTTON

In ancient times, when people looked up at the night sky, the stars were more vivid than they are today, as there wasn't the light pollution of modern times. People came to recognise patterns in the arrangement of stars. To them, one group of stars might look a bit like a woman seated on a throne, another like a dog or a bear. They wove these characters into the stories they told, interweaving culture with pinpricks of light.

Today we call these patterns of stars constellations. The word 'constellations' is derived from Latin and means 'set of stars'. These largely stem from ancient Greek interpretations of the star patterns in the night sky. However, this is just one interpretation of star patterns. Different people and cultures have seen completely different patterns in the stars and related them to their own history, surroundings and stories.

Take, for example, a very easily recognised pattern of seven bright stars within the constellation of Ursa Major. In the UK and Ireland, this 'asterism' of seven stars has traditionally been called the Plough, as it resembles the ard-type ploughs used to break up soil ready for planting seeds. Such ploughs were once commonly used across the UK and Ireland, so its name suggests that people saw something of their own lives depicted in the night sky.

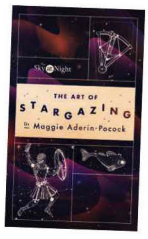
Different cultures in what are now India, Europe and North America held that these stars formed different shapes familiar to them. For some this was the tail of a 'great bear'. In the Inuit tradition, the same stars are seen as a caribou or reindeer. In Burma, stars in this part of the sky are associated with crustaceans (the family of creatures that includes lobsters, prawns and crabs). These are all reflections of the local wildlife that each culture knew.

In Vietnam, the seven stars have traditionally been seen as a rudder; fishing boats still navigate by these stars, so the name seems to come from their usefulness. They're seen as a boat or canoe by other cultures across Asia, perhaps for similar reasons. In China, the same stars make up one of several walls enclosing the north celestial pole, perhaps echoing the great walls built across that country. The stars are also linked to figures from Chinese religion, showing that the same stars can have more than one meaning for the same culture at once.

In the Philippines, these same stars are identified as a traditional kind of pot of cleansing water. In the US, they're a 'big dipper' or ladle.

Of course, there's no correct interpretation of any pattern of stars: one culture's meaning is as valid as any other. But using different patterns and names could make it difficult for astronomers to know which stars or parts of the sky are being referred to. So in 1928 the International Astronomical Union officially adopted the 88 constellations that the science uses today to maintain consistency.

Maggie Aderin-Pocock is a presenter on *The Sky at Night*. This is an extract from her new book *The Art of Stargazing*, published by BBC Books, out now



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BBC Sky at Night MAGAZINE

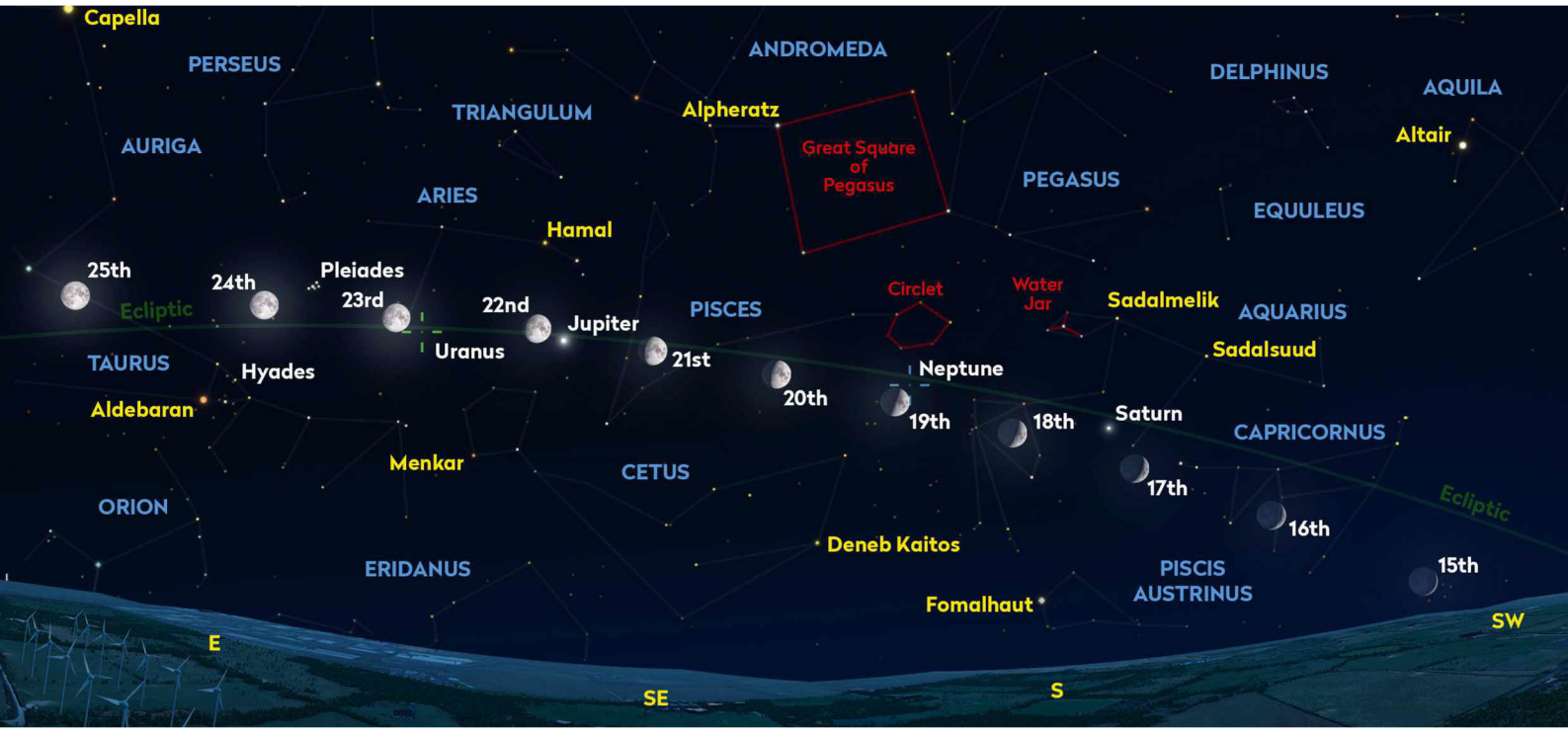
A December GRAND TOUR

Just like the epic journeys of the Voyager probes to our Solar System's outer planets, this tour takes you to the gas and ice giants as they line up in the night sky this month. **Stuart Atkinson** is your guide

This month the heavens align to give you night after night to enjoy views of the outer worlds in our Solar System

One of the greatest achievements in the history of space exploration was the Grand Tour, NASA's ambitious mission of the late 1970s and '80s to visit the Solar System's outer planets using the twin Voyager space probes. They flew from world to world in a series of fascinating fly-bys, sending back incredible images of the planets which are still iconic today.

There will never be another Grand Tour, but this month we will be able to go on our own 'Grand Tour' of Jupiter, Saturn, Uranus and Neptune as the four planets will be stretched out across the heavens in a long line. Observers with Go-To telescopes will be able to navigate from one world to another just by pressing a few buttons, but less experienced observers will find they have help from the Moon, which will hopscotch along the planetary parade over the course of a week in December.



▲ **How the four planets in our Grand Tour appear in December and the location of the Moon, which serves as your handy pointer to them. Positions shown as at 17:30 UT on the dates given, as seen from the centre of the UK**

The big picture

Go out on any clear night, or morning, and the chances are that there will be at least one planet in the sky for you to enjoy looking at with just your eyes or through binoculars or a telescope. Sometimes a couple of Earth's distant sister worlds come together in the same part of the sky – a grouping astronomers call a conjunction – which can be a lovely sight and very photogenic too.

Occasionally, if they align just the right way, we're treated to a veritable parade of planets spread out across the sky in a cosmic daisy chain. This is exactly what's going to happen this month: all of the outer planets will be on view in the sky after sunset, conveniently arranged in a line stretching from the southeast to the southwest.

The planets will be spread along part of an imaginary line in the sky called the ecliptic. This is a narrow band of sky which the Sun and its planets appear to move along as we, and they, orbit the Sun.

The huge gas giants Jupiter and Saturn will be visible to the naked eye, as they always are, looking like bright stars, but you'll need some help seeing the two farther-away ice giants. With a magnitude of +5.8, Uranus will be technically visible to the naked eye, but will probably require help from a pair of binoculars. Neptune, the most distant world in our Solar System, will be visible through binoculars too, but a telescope will really help you identify it by highlighting its subtle colour.

If you don't know the night sky very well, or if you don't have much experience of planet spotting, don't worry. During the latter part of December, the Moon will move down the planetary parade line, encountering each planet in turn, which – along with the information in this guide – will help you identify which one is which. Let the tour begin! ▶

Stuart Atkinson is a lifelong amateur astronomer and author of 11 books on astronomy

Saturn

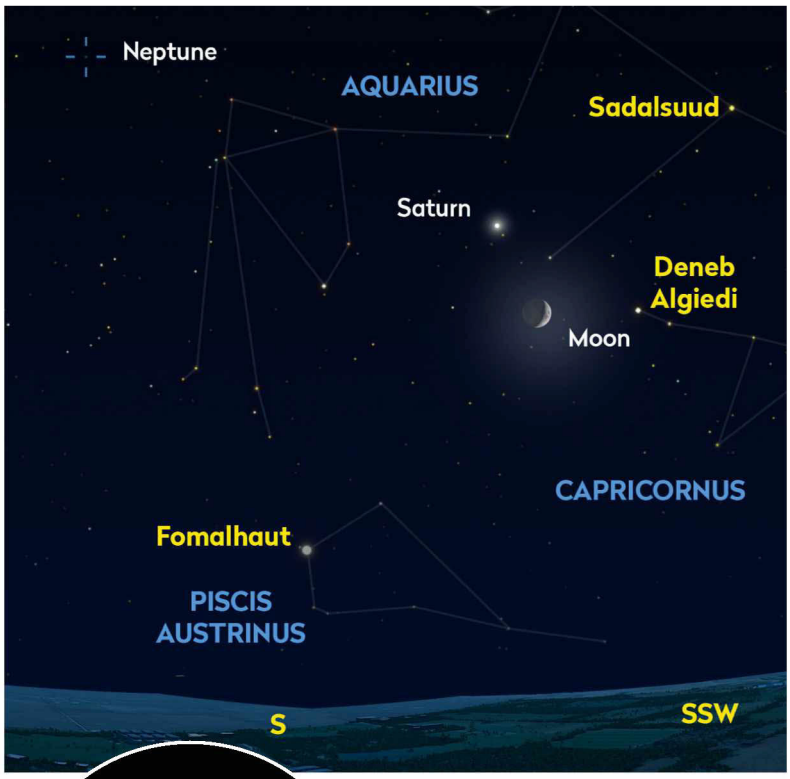
A once-every-176-year alignment allowed the Voyager probes to visit all four of the giant planets. Saturn was the second stop, where in 1980/81 they recorded its fine cloud patterns, complex rings and aurorae at its poles before getting a good look at the icy surfaces of several of its moons

We'll start our Grand Tour by going out at around 17:00 UT on **17 December** and looking towards the south, where – unless you have a lot of trees, tall buildings or hills on your skyline – you'll see Saturn shining low in the darkening twilight sky.

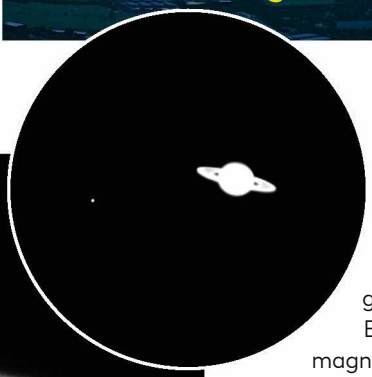
Saturn will be in the constellation of **Aquarius**, looking like a yellow-white star beneath the constellation's well-known, spearhead-shaped **Water Jar asterism**. Shining at magnitude +0.9, Saturn will be clearly visible to the naked eye, but you won't have long to see it; by mid-month, Saturn will be setting in the southwest at around 21:30 UT.

Saturn is of course famous for its beautiful system of icy rings that have entranced astronomers ever since Galileo glimpsed them with his first crude telescope in 1610. Today we have stunning high-resolution images of those rings and the gaps between them, taken not just by the Voyager crafts but by Cassini, Hubble and the JWST too.

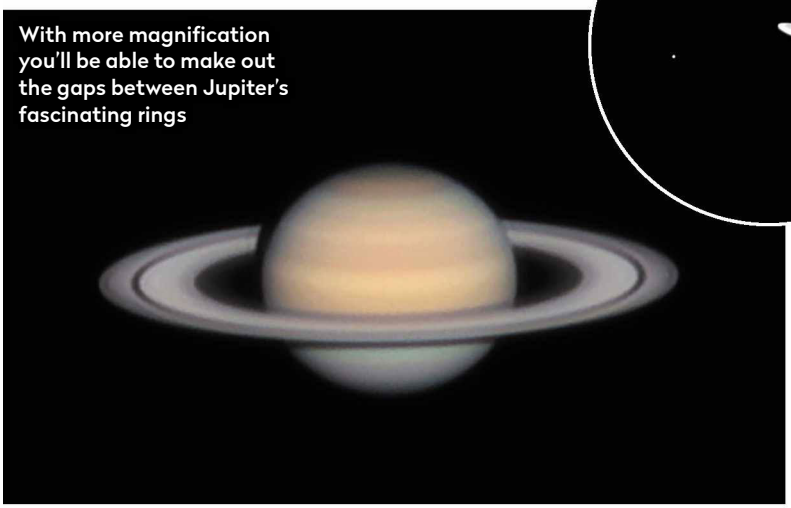
If you want to see Saturn's rings for yourself you'll need a telescope, because standard binoculars aren't powerful enough. And don't delay: the rings are slowly closing up from our perspective on Earth, and within a few years will be edge-on to us and all but invisible. A 6-inch telescope and high magnification will show you the widest gap in Saturn's rings, the dark Cassini Division, and through a larger telescope under a clear, dark sky you'll be able to pick out smaller ring gaps in moments of good seeing too.



▲ Saturn will be to the left of a crescent Moon at 17:30 UT on 17 December



◀ Binoculars should show you the planet, but use a telescope to pick out its giant moon Titan

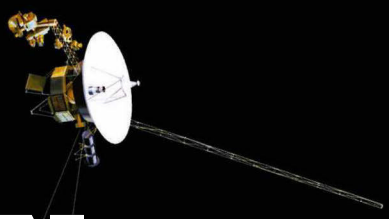


With more magnification you'll be able to make out the gaps between Jupiter's fascinating rings

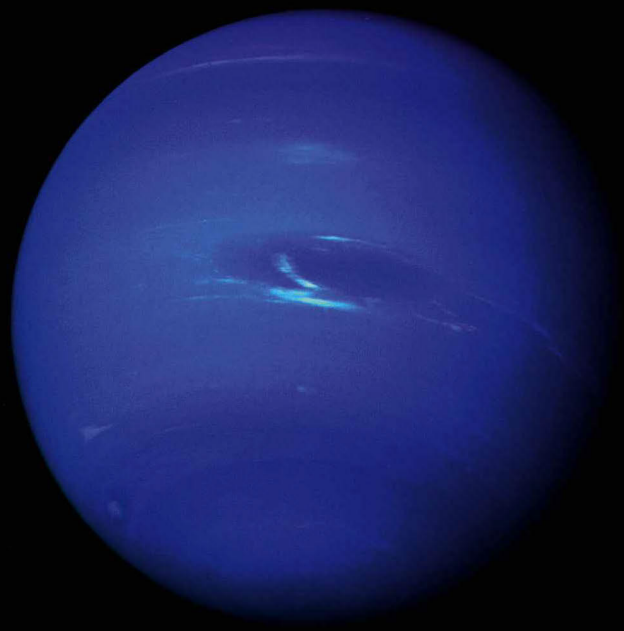
But there's more to Saturn than its magnificent rings. Even a small telescope will reveal that its creamy disc is flattened at its poles, and will also show you its largest moon, Titan. Titan is as big as the planet Mercury, and if it orbited the Sun on its own it would be big enough to be considered a planet in its own right.

On the evening of **17 December**, a lovely **crescent Moon** will be shining to the lower right of Saturn, helping you to identify it. The following evening, the Moon will have moved to shine on the planet's left.

NASA/JPLX 2, CHARTS BY PETE LAWRENCE. NEPTUNE: PETE LAWRENCE, MICHAEL KARRER/CCDGUIDE.COM, FRITZ SUSSMANN/ CCDGUIDE.COM



Neptune



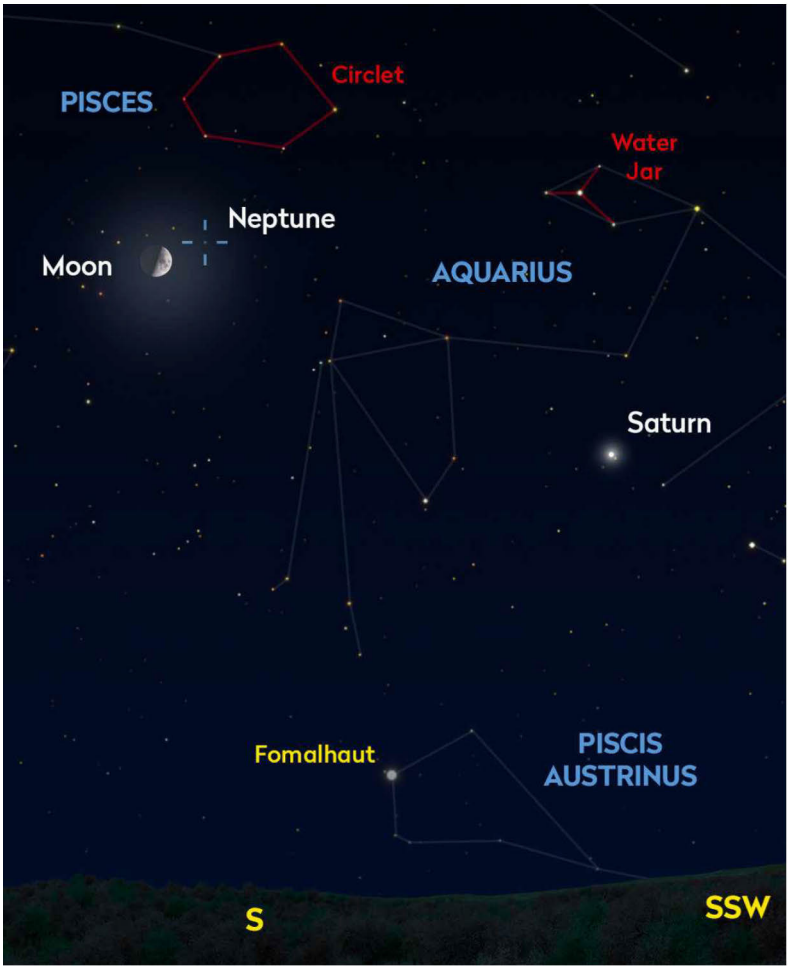
It was 1989 by the time Voyager 2 reached Neptune, the last of the big four worlds, capturing its Great Dark Spot on camera, as well as its rings and the cloud bands in its fast-moving atmosphere, even discovering six new moons. Star of the moon show was Triton, never visited before or since, revealed to be a world of craggy ridges with several-kilometres-tall geysers shooting from its crust of frozen nitrogen

The next stop on our festive Grand Tour is Neptune. This ice giant world is four times the size of Earth, with a system of dark rings and a small family of icy moons. Ever since Pluto was controversially stripped of its planetary status in 2006, Neptune has officially been the farthest planet from the Sun. In fact, Neptune is so far away that Earth completes 165 orbits of the Sun in the time it takes Neptune to travel around it just once. In December, Neptune will be around 4.5 billion kilometres away and its faint light will take more than four hours to reach us.

In December you'll find Neptune in the constellation of **Pisces**, just below the well-known **Circlet asterism** and a little more than 22° over to the east, or left, of **Saturn**. Unlike Saturn, Neptune will be much too faint to see without some kind of optical assistance, even if you're lucky enough to be looking for it in a dark sky with no light pollution.

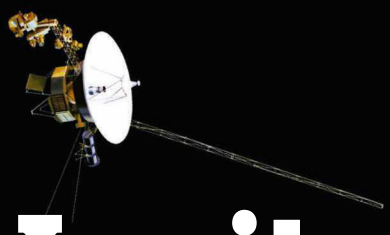
▶ Ice giant Neptune and its largest moon, mag. +13.5 Triton, which appears like a faint, blurred star

▼ A telescope is your best bet to see Neptune on 19 December, very near the Moon in Aries. View shown at 17:30 UT

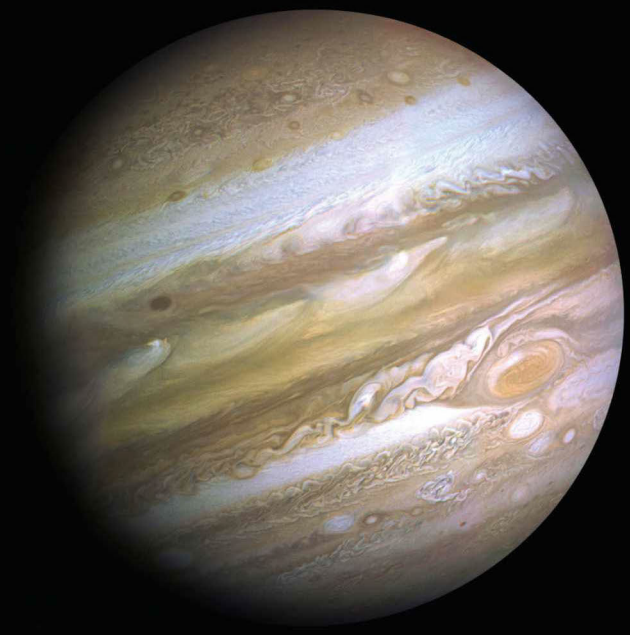


With a magnitude of +7.9, Neptune is visible in binoculars, but you have to know exactly where to look; there are so many stars of the same brightness around it that it's very hard to pick it out. However, if you have a telescope it will enhance the planet's blue-green hue. Using a large telescope and high magnification you'll see the planet's disc and really appreciate its subtle turquoise colour too. Just don't expect to see any of the dark cloud bands or bright storm systems that Voyager 2 did in 1989, even though those images regularly and very misleadingly appear on telescope boxes...

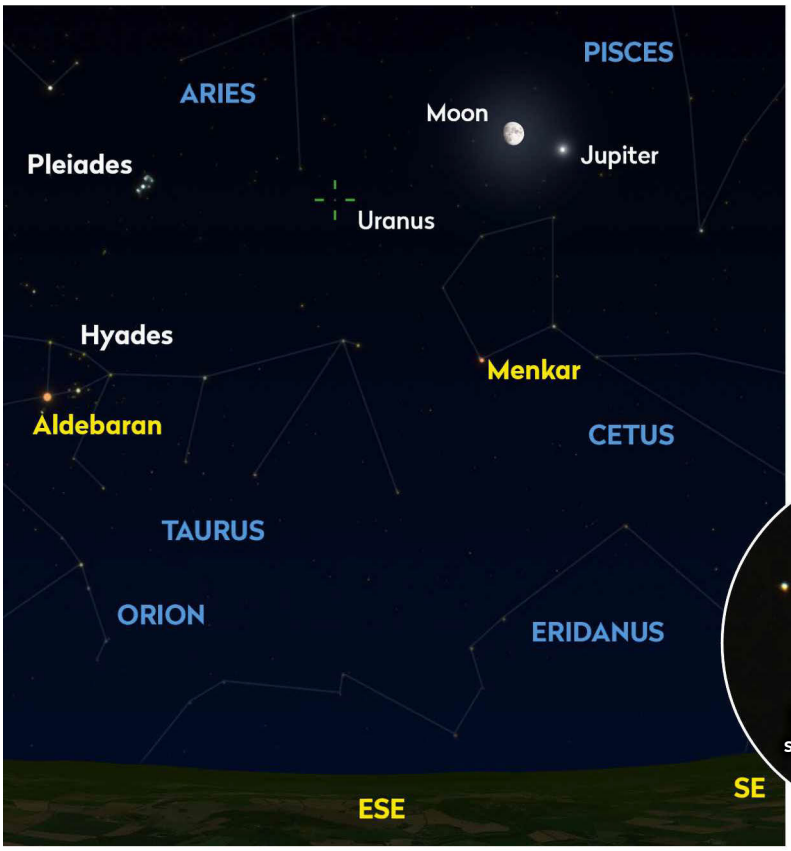
Faint Neptune will be the trickiest planet to identify on our Grand Tour, but thankfully help will come from the Moon. On the evening of **19 December**, the **first quarter Moon** will shine just 2.5° away from Neptune. On that evening, if you centre the Moon in your binoculars, Neptune should be in the same field of view, a pale blue-green 'star' shining away to its upper right. ▶



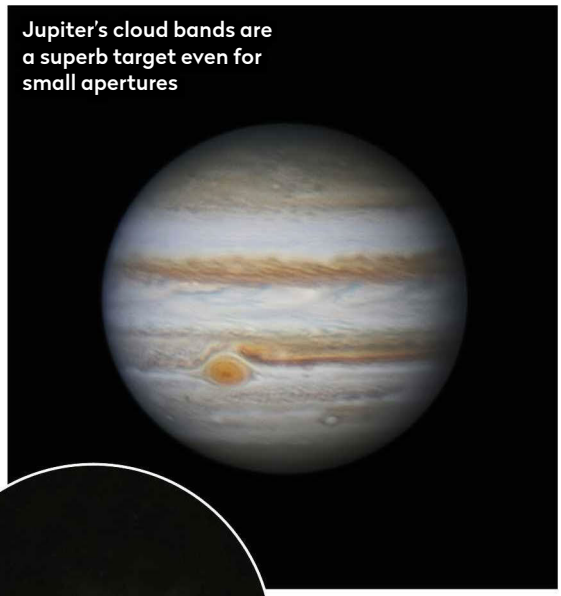
Jupiter



Voyager 1's first rendezvous was with Jupiter, making its closest approach in March 1979. With Voyager 2 picking up the baton weeks later, between them they took over 33,000 images of the world and its five main satellites, discovering the huge cyclonic storm that creates the famous Great Red Spot, spotting lightning and – most surprising of all – seeing active volcanism on moon Io



▲ **The view on 22 December at 17:30 UT. Jupiter will be over to the southeast, very bright and impossible to miss**



Jupiter's cloud bands are a superb target even for small apertures

Regular binoculars will show the four pinballing Galilean moons

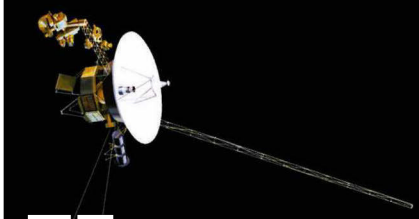
Of all the planets out on parade in the evening sky in December, Jupiter will be the easiest to find and identify because it will be the brightest. If you look to the southeast as the sky grows dark, Jupiter will be there, right in front of you, blazing away like a blue-white star, brighter than any other star or planet in the sky at that time.

It's no surprise that Jupiter is so bright, because even though it is around 638 million kilometres away from us in December, it is the largest planet in our Solar System, so reflects a lot of light in our direction. A bloated ball of hydrogen and helium gas with a rocky core, the gas giant planet could contain a thousand Earths with room to spare.

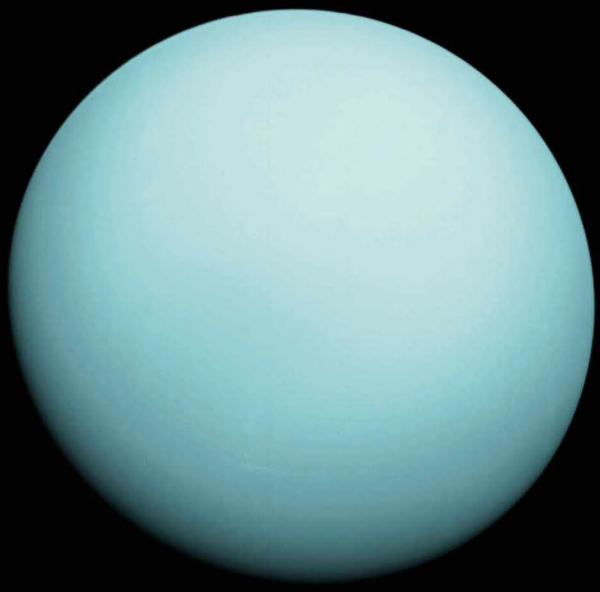
As impressive as Jupiter looks to the naked eye, it looks much more impressive with a little magnification. If you swing your binoculars towards Jupiter you'll see up to four little stars shining close to it. These are actually some of its extended family of moons (95 at the last count!). The number you will see, and how they are arranged, will depend on which night you look; both change as the moons whizz around Jupiter like cyclists on a race track.

Seen through a telescope, Jupiter is a wonder. Even a small telescope will show its pale disc crossed by two dark cloud bands, and larger instruments will also show its famous Great Red Spot storm system, more light and dark bands, and colourful ovals and streamers of material in its atmosphere.

Because Jupiter will be so bright, you won't need any help finding it in the sky, but on the evening of **22 December** the **waxing gibbous Moon** will be very close to it, shining just 4° away to its upper left. The pair will be a lovely sight in binoculars for those under clear skies. Also, when you spot Jupiter you'll notice that it is shining to the right of a misty patch of light. Look more closely at that and you'll see this is the famous **Pleiades** or Seven Sisters star cluster.



Uranus



Going it alone – Voyager 1 having departed for the edge of our Solar System – Voyager 2 made its closest approach to Uranus in January 1986. The first and as yet only human-made object to get up close to the distant planet, it radioed back data on its rings, its high-speed winds and peculiar magentic field, took spectacular images of its five largest moons and discovered 10 previously unseen ones

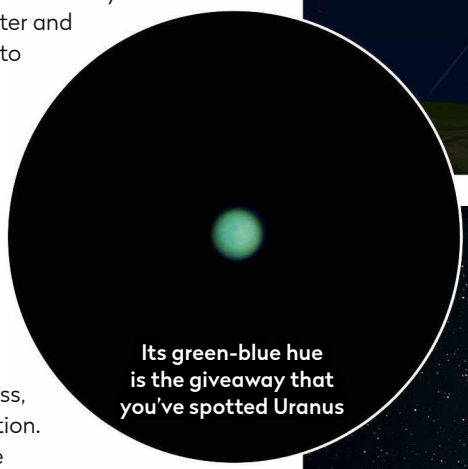
The final stop on our Grand Tour is Uranus. Like Neptune, Uranus is an ice giant planet, a frigid world with dark rings and cold, dark moons. It is so far from the Sun that its year is 84 Earth years long.

Although, like Neptune, Uranus is a giant world more than four times the size of our own, its great distance from us – 2.8 billion kilometres in December – means that it is very faint. With a magnitude of +5.7, it is just visible to the naked eye, but really only if you're looking for it in a dark sky well away from light pollution. Even then there are so many stars of the same brightness as Uranus that you have to use a good chart to pin it down. The planet is more easily identified using binoculars, which show how its subtle and unusual green colour makes it stand out from the myriad blue and white stars twinkling around it.

In December, Uranus will lie in the constellation of **Aries**. It will already be above the horizon at sunset and will set around 05:00 UT the next morning, giving you plenty of time to find it shining roughly half-way between bright **Jupiter** and the **Pleiades** star cluster. Jupiter is the key to finding Uranus. If you aim your binoculars at Jupiter and then pan them very slowly to the left, you'll soon come across a 'star' with a pale, almost mossy-green hue. That's it; that's Uranus. Your binoculars won't be powerful enough to resolve the planet's disc – you'll need a telescope for that – and it's so distant that the disc will only be small and featureless, even under high magnification.

Although Jupiter and the Pleiades will be very useful pointers to help you find Uranus, if you need a little extra help then look for the **almost-full Moon** on the evening of **23 December**, which will be just under 4° away, to its upper left.

The view at 17:30 UT on 23 December. Pan slowly from Jupiter to find Uranus



Its green-blue hue is the giveaway that you've spotted Uranus

▶ The Pleiades provide a helpful waymark as Uranus sits mid- way between the cluster and Jupiter this month

The cosmic microwave background – the afterglow of the Big Bang – is loaded with clues about how the Universe formed

The remains of CREATION

UNDERSTANDING THE CMB

Left over from the Big Bang, the cosmic microwave background gives astronomers an insight into the entire history of our Universe. **Ezzy Pearson** explains

ILLUSTRATION ALEKSANDARNAKOVSKI/ISTOCK/GETTY IMAGES, ESA AND THE PLANCK COLLABORATION

Light is the window through which astronomers view the cosmos. It fills the Universe. Once light has been emitted, it travels on and on, moving constantly at the speed of light. It only stops when it hits something, be it a gas particle, a planet or even a black hole.

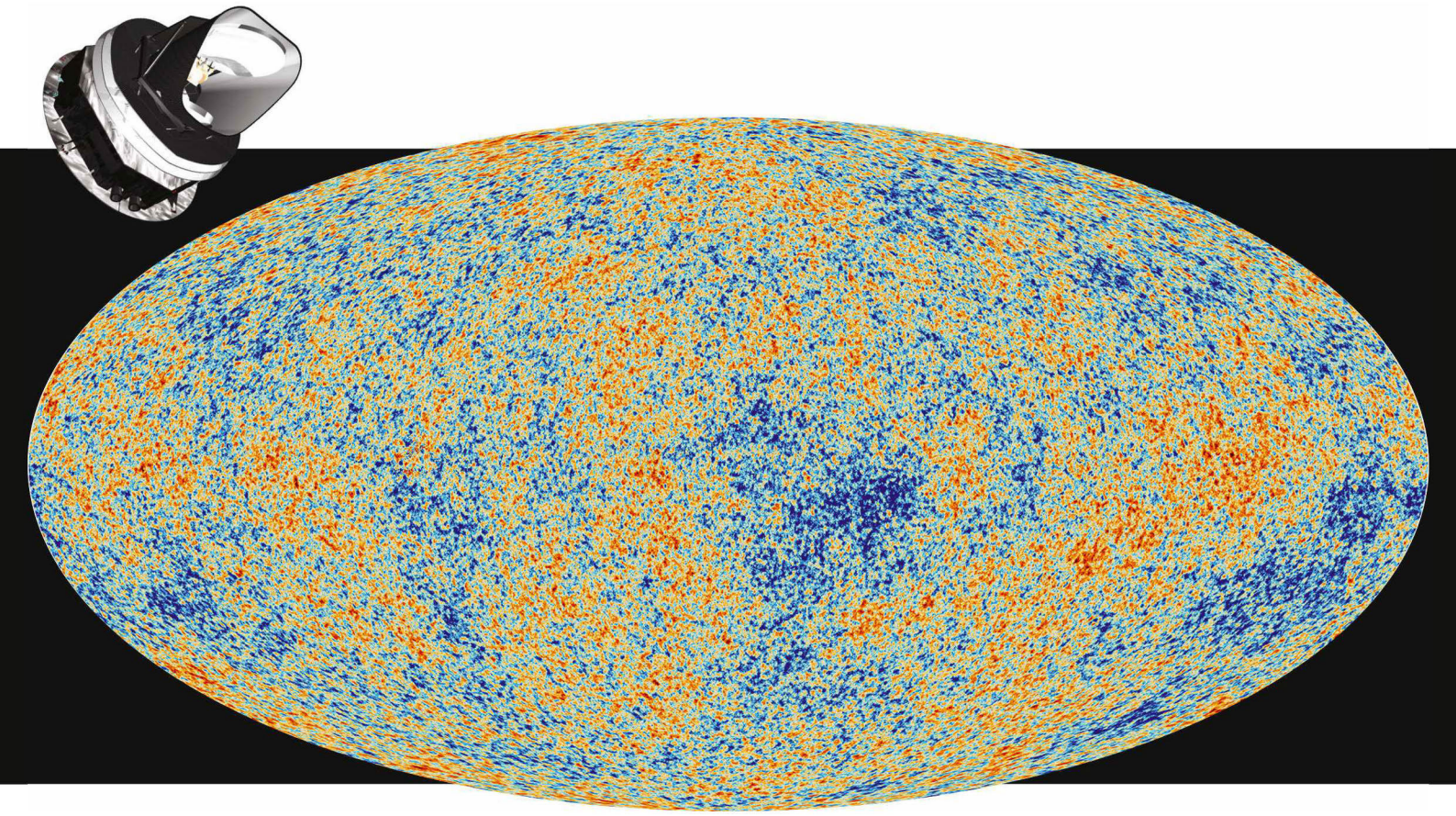
Because of light's eternal nature, we see distant galaxies not as they are now, but as they were when their light was emitted. If it has taken the light from an object a billion years to reach us from a galaxy, then we see that object as it was a billion years ago. Look far enough away, and you could view all the way back to when the first stars began to shine.

Look back even further and it's possible to see light from the very earliest days of our Universe's existence, which we see now as the cosmic microwave background (CMB).

"The simple way to explain the CMB is as the very first light ever emitted in our Universe," says Erminia Calabrese from Cardiff University. "It's been travelling from that moment all the way to today."

In the beginning...

The Big Bang theory states that in the very first moment of the Universe, all the energy and matter of the cosmos was at an infinitely dense point. In the initial fractions of a second of existence, this rapidly expanded, cooling as it went. When the Universe was a second old, it was cool enough for that energy to take on the form of matter particles – such as protons, neutrons and electrons. It also formed light particles known as photons, setting the entire Universe aglow long before the first stars began to shine. ▶



▲ **In 2013, the Planck mission captured the CMB, imprinted on the sky when the Universe was just 380,000 years old, in greater detail than ever before**

▶ Within the first few minutes, protons and neutrons joined together to form positively charged nuclei, but the negatively charged electrons were so hot they could evade being caught. They floated free and so were able to easily absorb and re-emit the light photons that filled the cosmos. For over 380,000 years, the Universe was filled with an impenetrable fog that prevented light from travelling more than a few fractions of a nanometre.

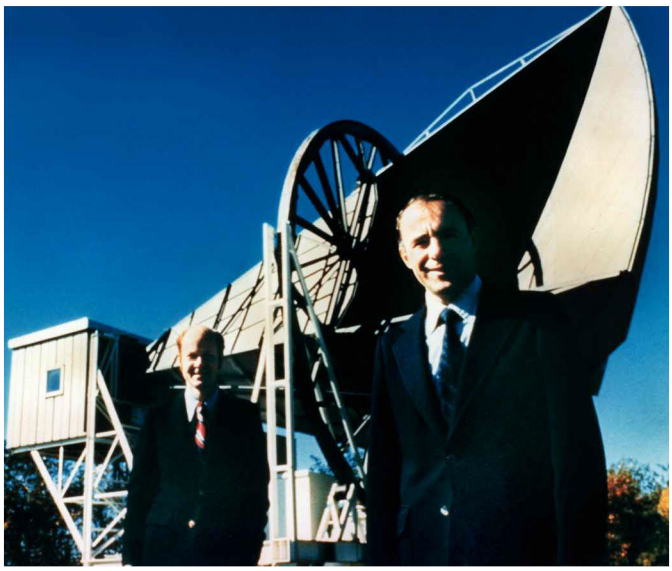
Then came a time known as Recombination. The Universe had cooled enough that electrons could no longer escape the electromagnetic pull of nuclei and were captured, forming the first hydrogen and helium atoms. Locked away, the electrons no longer absorbed photons, so light could traverse the now transparent cosmos. This was the moment when the CMB was formed.

For the next 13 billion years, this light has journeyed through the stars, but it has not remained unchanged. The very fabric of space-time has expanded during this time, stretching the light travelling through it. This increases its wavelength, meaning visible light has become redder. The radiation from the Big Bang has been travelling for so long it's been stretched beyond visible wavelengths, through the infrared, to become microwave radiation.

This radiation exists everywhere in the Universe, travelling in every direction, but what we see as the CMB is the light that originated over 13 billion years ago, and is only now reaching us. The presence of this radiation was predicted in the 1950s, but it wasn't actually discovered until 1964.

Even then, radio astronomers Arno Penzias and Robert Woodrow Wilson at the Bell Telephone Laboratories in the USA initially thought the signal was an error in their equipment. But when they reported it as a "radio transmission of unknown origin", theorists immediately recognised the signal they'd been looking for. Cosmologists have been mapping the CMB in increasing detail ever since.

▼ **Arno Penzias and Robert Woodrow Wilson were the first to detect the CMB in 1964**

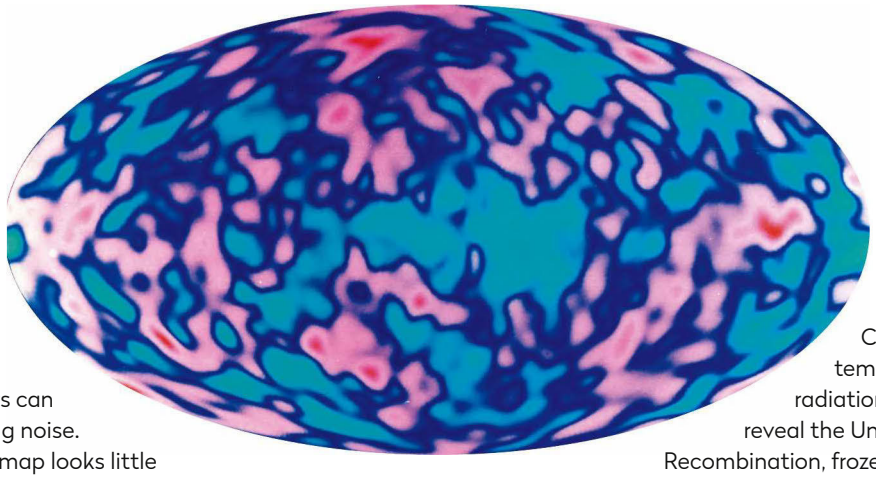


Noise reduction

"We have entire teams and institutions that simply focus on designing the technology and instrumentation that is required to go after these tiny signals," says Calabrese. "There is a huge effort in developing very precise cameras and sensors that you then put on very advanced telescopes, either on the ground or that you launch into space with a satellite."

Early maps could only make out the vague shape of these regions, but the most recent map by ESA's Planck satellite contains a striking amount of detail. Revealing this detail is somewhat of a challenge however, as it is buried under all that the CMB has passed through during its 13-billion-year journey through space. The movement of our Galaxy and the dust within it are just two sources of noise that change and twist the view of

PLANCK SPACECRAFT: ESA, ESA AND THE PLANCK COLLABORATION, SCIENCE HISTORY IMAGES/ALAMY STOCK PHOTO, GETTY, STRATOCAT



▲ In the 1990s, NASA's COBE revealed the large-scale shape of the entire CMB, but it lacked fine detail

the CMB we see. In fact, the CMB is just a tiny fraction of the initial measurement the telescope picks up. Through meticulous corrections, astronomers can clear away this obscuring noise.

Though the resulting map looks little more than a sea of blobs to the untrained eye, to those that know how to look, these colourful patches reveal the history of our Universe from the first moment of the Big Bang until today.

"Because it's been there forever, from the very beginning all the way to today, the cosmic microwave background has picked up signals and information," says Calabrese. "It's been watching out for us. Sometimes I use the example of your great-great-grandfather who has lots of stories to tell you of all the things they've gone through, and they are now here to tell you all about it."

There are three main areas to examine when looking at the CMB. First is the temperature of the radiation. These fluctuations reveal the Universe as it was at Recombination, frozen in time 380,000 years after the Big Bang.

A journey through time

Then there is the polarisation of the light, which shows how the CMB photons scattered off other particles. This showcases two key epochs in cosmic history. The first is Recombination, when the CMB was set down. The other is known as Reionisation, a time just after the first stars began to shine. Their light ionised the surrounding gas, knocking an electron off each atom so they could interact with light photons again. ▶

Taking a look at the CMB

Examining the CMB is difficult, but astronomers have found many ways to go about it

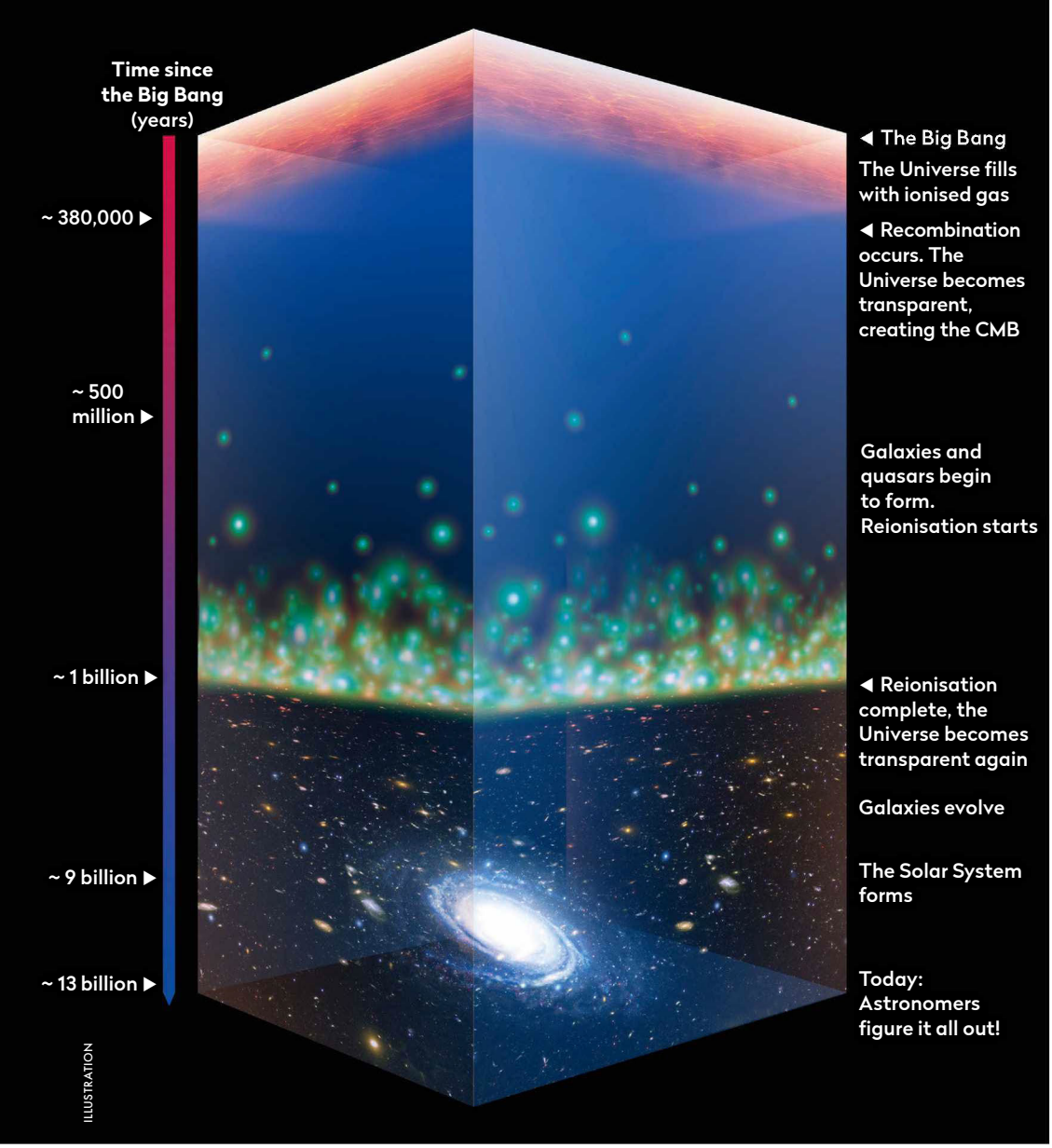
The first observations of the CMB were made from the ground, and there is one big advantage to doing so: the picture can be put together with very large dishes. The larger a telescope is, the greater its resolution, meaning a ground-based telescope can obtain a great amount of detail. However, they are also locked to a single location and so are unable to map the entire sky. Plus, water and oxygen in the atmosphere absorb microwaves, blurring the view. While telescopes built on top of mountains can get past the worst of the atmosphere, the only way to avoid it entirely is to get above it.

One way to do this is to go into space. There have been three such missions to date: NASA's Cosmic Background Explorer (COBE) from the 1990s, the Wilkinson Microwave Anisotropy Probe (WMAP) in the early 2000s and ESA's Planck satellite in the 2010s. A fourth, LiteBIRD, is being developed by the Japanese space agency, with a planned launch by 2030 (see page 14 for details). Such missions can map the entire sky with incredible precision, but they're expensive and their size is limited by what will fit on a rocket.

The final group of observatories split the difference by dangling a telescope from beneath a weather balloon. These can reach altitudes of 50km, where the atmosphere is practically non-existent, and while they can't rival the size of ground-based observatories, they can be made larger than space-based telescopes. The trade-off is controllability: there is no way to steer a balloon, so you are limited to observing from wherever the weather takes them.

What's more, weather balloons can only survive so long before bursting, meaning your telescope has to be able to survive a 50km drop. Most balloon observatories use parachutes to cushion the landing, but even this is fraught. In 2006, one mission's parachute failed to detach once it landed, dragging the telescope across the Antarctic landscape and destroying it.

Balloon-mounted observatories are a cheap, but risky, way to study the CMB



ILLUSTRATION

▲ **A brief history of Recombination and Reionisation**

▶ Finally, there is the weak lensing signal. The gravity of large objects can bend the path of light travelling past. During its travels, the CMB photons traverse along chains of galaxies and through clusters, all of which deflect the path of photons, leaving their mark on the CMB map.

"This is something that we get by combining temperature and polarisation," says Calabrese. "What this is capturing is all the deviations and fluctuations that these photons felt as they were travelling from Recombination through the large-scale structure. We want to map and measure [the weak lensing signal] really well because the gravitational lensing effect directly translates into the geometry, matter content and distribution of the Universe."

But getting all this information out of the maps is far from a trivial matter, as Calabrese explains. "It's not like discovering a new galaxy," she says. "It's not like saying, I want to find out if there's an object over there and going and spotting it. All the different physics is baked together in those blobs that we see. To understand it, we need to come up with some quantities that then we can more easily interpret."

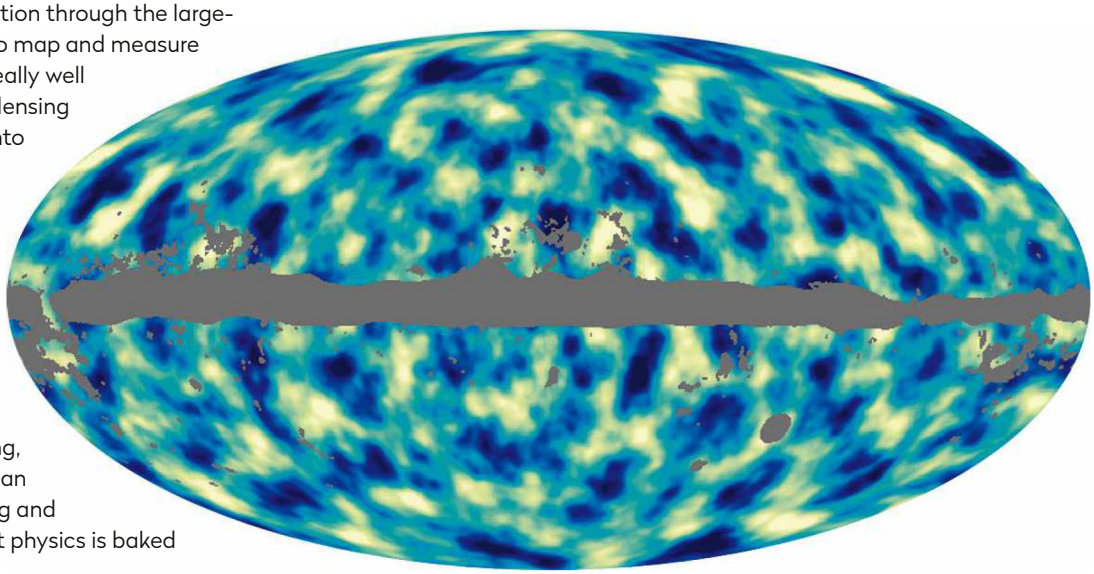
They do this by conducting a statistical analysis of the maps, examining factors such as the size of the blobs, their temperature or how they are grouped together. But this isn't what cosmologists really want to know. They want to find out what age the Universe is, what kind of matter it's made up of and what rules control how it has grown over time. To be able to extract that information, cosmologists must first create their own universes.

"We write down some very complicated equations and predict what a CMB signal would look like if the Universe had a specific composition, or age, or property," explains Calabrese.

These equations are based on our current understanding of how the Universe operates. Using these, 'model' universes are created that can then be analysed. "You take the model and look at the blob distribution and compare it with your observations. You reverse the process," says Calabrese.

In this way, cosmologists are able to reverse-engineer the properties of our Universe. With increasing access to supercomputers and advancing

▼ **An all-sky map showing the lensing effect massive cosmic structures have on the CMB**



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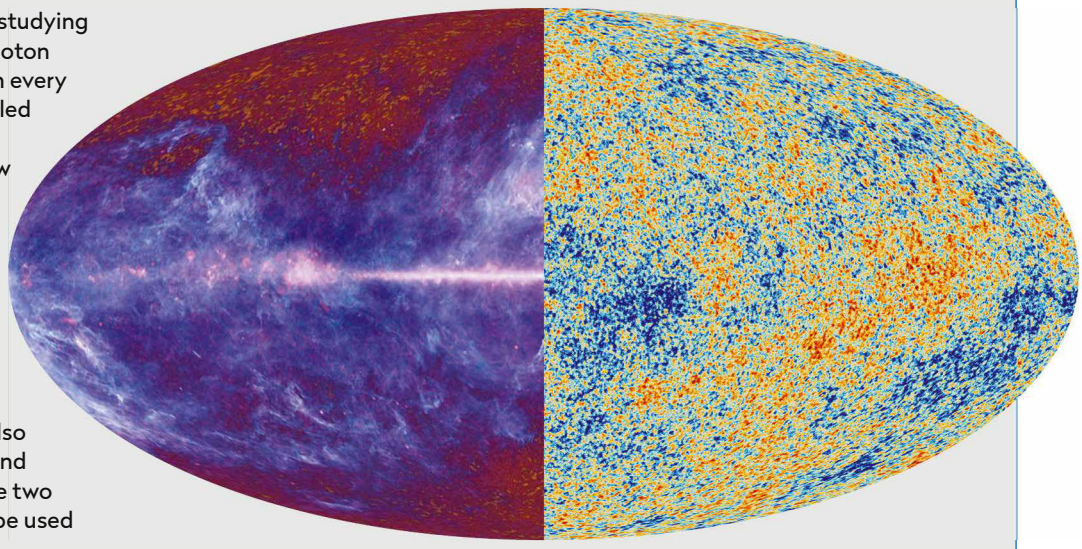
Drowning out the noise

Astronomers have to wade through a sea of information to get to the CMB signal

One of the biggest issues with studying the CMB is noise. Each CMB photon has picked up information from every stage of the Universe it's travelled through, meaning the initial fluctuations make up only a few per cent of the signal picked up by an observatory.

Throughout its journey, a light photon has been bent and distorted by the large-scale structure of the Universe, resulting in the weak lensing signal. This not only changes its path slightly, but also distorts both its temperature and polarisation, and so using these two measurements in concert can be used to extract that signal.

Next, the photon enters our Galaxy, where it encounters a variety of obstacles. The Milky Way's magnetic field again affects the polarisation, which needs to be compensated for. Dust and gas add in more radio waves that pollute the signal, meaning these areas need to be carefully mapped or masked.



▲ Planck's one-year all-sky survey data from 2010 was initially polluted by bent photons and galactic dust (left), but was carefully cleaned to produce the CMB map

analytical techniques, they're able to develop ever more detailed simulations to pick apart the increasingly precise maps being produced by every new generation of telescope.

"Over the last two decades we've had a huge jump in quality and quantity of our data," says Calabrese. "That means the answers we get out from them are extremely precise."

Ever-sharper focus

When looking at such huge distances with so many sources of interference, the error margins have the potential to be huge. But while cosmology has historically been a very imprecise science, that is no longer the case.

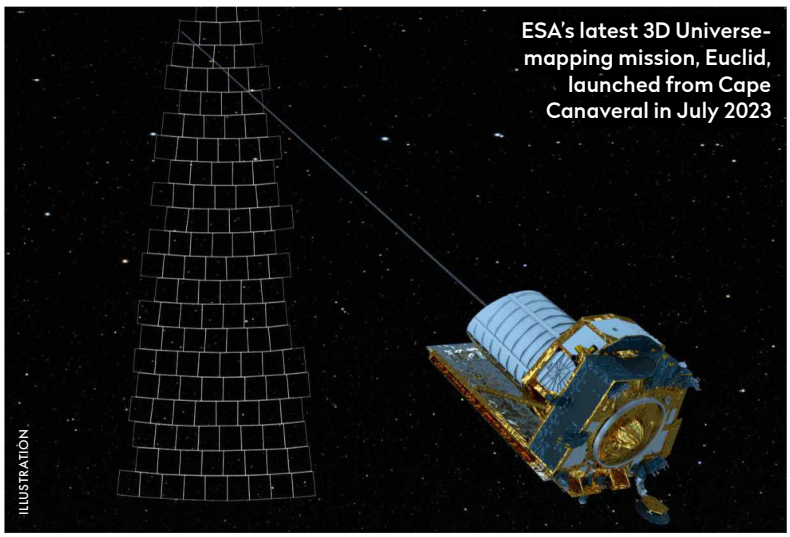
To give one example, when astronomers looked at the data from COBE back in the early 1990s and attempted to determine how much normal matter made up our Universe, they could only say it made up somewhere between 2 and 7 per cent of our Universe's mass. However, when they repeated the measurements with the most recent maps from Planck, they calculated that it made up 2.2 per cent of the overall mass of the Universe, with an error margin of just 0.015 per cent.

"What we see is really an astonishingly perfect agreement between the observations and the models," says Calabrese. "The data is so good that all the key parameters of the model are constrained to sub-per cent precision."

This precision has made the CMB a powerful tool in many other areas of astronomy as well. Upcoming observatories such as Vera Rubin, Euclid and the Dark Energy Survey are all set to map out huge areas of the sky over the next few years. Their aim is to build 3D maps of the Universe to understand the distribution of matter throughout the cosmos – just as the weak lensing data from the CMB will do.

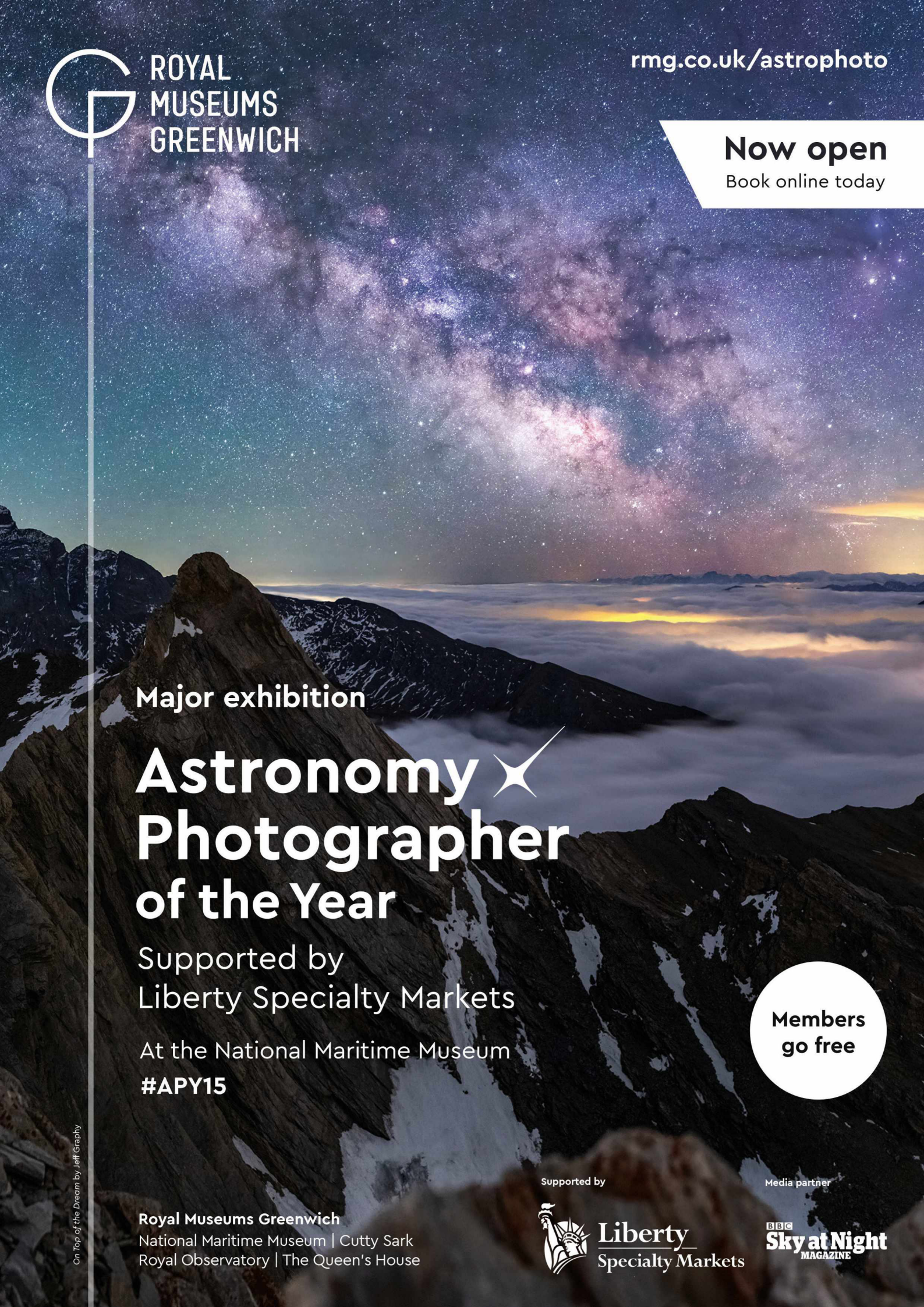
"This will give a lot of opportunities for science across different surveys that will enable things that a single experiment wouldn't be able to do on its own," says Calabrese.

The CMB is a magnificent tool, and through studying it astronomers are able to get closer to understanding the true origins of our Universe with every passing year.



ESA's latest 3D Universe-mapping mission, Euclid, launched from Cape Canaveral in July 2023

Ezzy Pearson is *BBC Sky at Night Magazine*'s features editor. Her book *Robots in Space* is available through History Press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16-PAGE CENTRE PULLOUT

The Sky Guide

DECEMBER 2023

GLORIOUS GEMINIDS

With no Moon to spoil the show, 2023's Geminid shower is set to round off a spectacular year of meteor displays

CATCH THE TRAIN

Take our challenge to photograph the lingering train of a shooting star

WINTER BINO TOUR

Six faint targets to find in Orion and Taurus

PETE LAWRENCE

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month...

- Two double shadow transits at Jupiter
- Vesta at opposition
- Morning crescent Moon near Venus
- Mare Orientale region

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

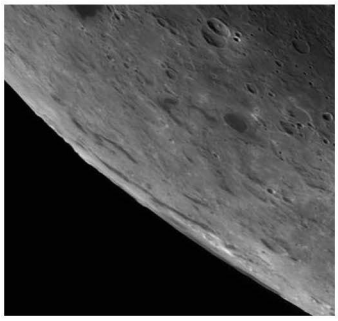
DECEMBER HIGHLIGHTS

Your guide to the night sky this month

Friday
1 An early-in-the-month start for our Deep-Sky Tour on page 56 takes advantage of the Moon moving into the morning sky. Observe before 20:00 UT on 1 December for the darkest sky.

Saturday ▶
2 Just before dawn, the 77%-lit waning gibbous Moon sits 3° to the north of the Beehive Cluster, M44.

Ganymede transits Jupiter from 03:08 UT until 04:56 UT.

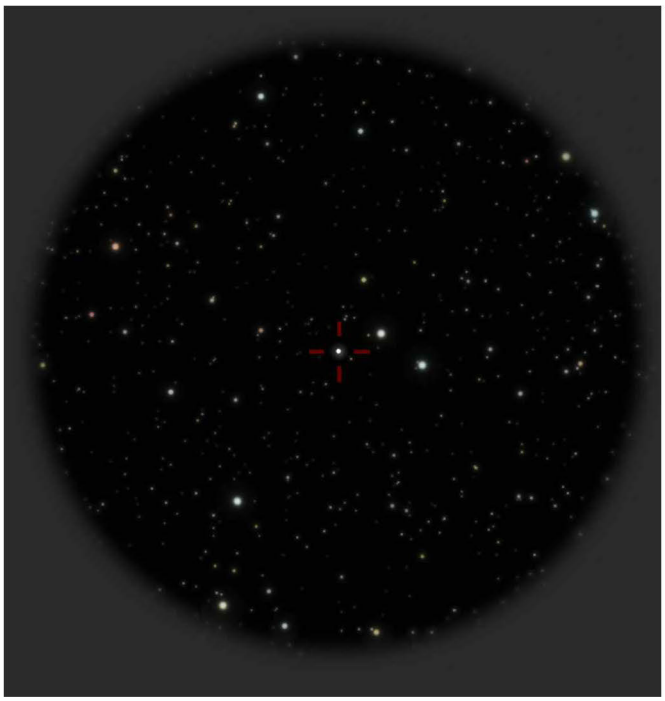


◀ Saturday
9 This morning, look for the 14%-lit waning crescent Moon less than 5° from mag. –4.0 Venus.

Reasonable libration for spotting Mare Orientale this morning.

Thursday ▶
14 The Geminid meteor shower peaks this evening, meriting an all-night watch. The theoretical peak occurs at 19:00 UT, but geometry and timing favour watches on 13/14 and 14/15 December.

Saturday
16 Ganymede's shadow transits Jupiter from 14:03 until 15:58 UT, starting in full daylight. As darkness falls, Europa will be in transit, its shadow also transiting from 16:47 until 19:11 UT.



PETE LAWRENCE X 8

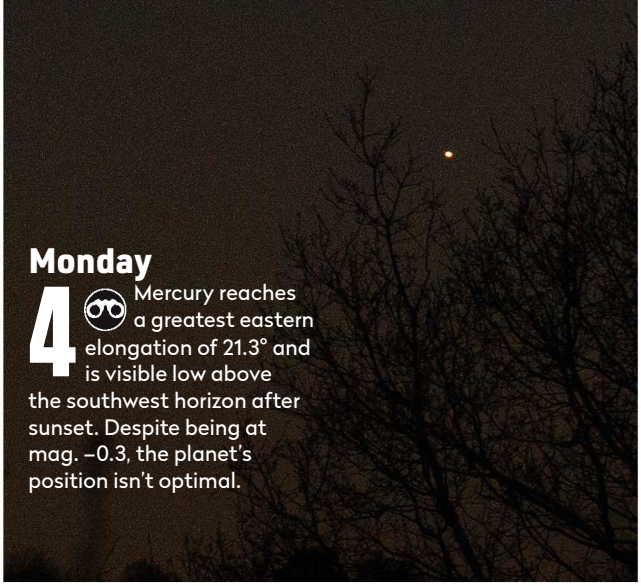
◀ Thursday
21 Vesta reaches opposition and can be seen shining at mag. +6.3 among the stars of northern Orion.

Friday
22 The Northern Hemisphere's winter solstice occurs at 03:28 UT.

Look for the 80%-lit waxing Moon less than 3° from mag. –2.5 Jupiter as the sky darkens this evening.

Sunday
24 Early this morning as it approaches setting, the 91%-lit waxing gibbous Moon will be 3.1° from the centre of the Pleiades open cluster.

Wednesday
27 Tonight and into tomorrow morning, comet 62P/Tsuchinshan will pass through the Leo Triplet of galaxies (M65, M66 and NGC 3628). It's predicted to be around mag. +7.2 at this time.

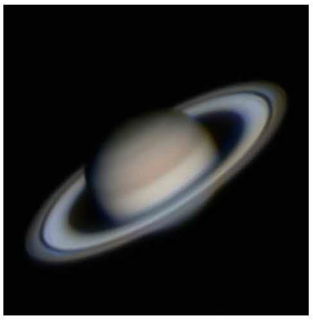


Monday
4 Mercury reaches a greatest eastern elongation of 21.3° and is visible low above the southwest horizon after sunset. Despite being at mag. –0.3, the planet's position isn't optimal.

Thursday
7 Io appears to chase the mag. +11.6 star GSC634-593 as it heads towards an occultation by Jupiter. The planet occults the star at 21:00 UT. The star reappears at 00:51 UT on 8 December.

Tuesday ▶
12 Jupiter's largest moon Ganymede is occulted by the planet, starting at 20:03 UT. Its reappearance begins at 21:41 UT.

Wednesday
13 Today's sunset is the earliest for the year.

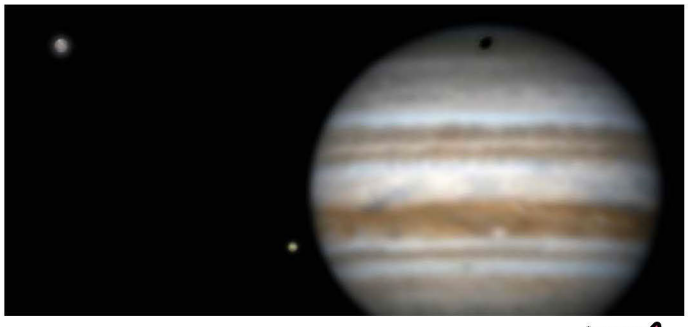


◀ Sunday
17 At 19:30 UT, the 27%-lit waxing crescent Moon sits just 4.3° below mag. +0.8 Saturn.

Callisto sits below Jupiter's southern pole at 21:49 UT.

Tuesday
19 Jupiter's largest moon Ganymede is occulted by the planet starting at 23:34 UT. Reappearance begins at 01:17 UT on 20 December.

Saturday ▶
23 Ganymede's shadow transits Jupiter between 18:04 and 20:00 UT. Europa's shadow also makes an appearance at 19:22 UT.



Saturday
30 Today's sunrise is the latest of the year.

Ganymede transits Jupiter from 17:13 until 19:17 UT. Europa follows suit between 19:38 and 22:01 UT.

Family stargazing

The Geminid meteor shower is arguably the best of the year. A high peak rate and long December nights make for good viewing if the Moon is out of the way, as is the case in 2023. If late nights are an issue, try to plan an early watch from say 20:00 UT on the evening of 13 December. Wrap up very warm, find a location away from stray lights and lie down on a sunbed. Any direction will do, but for interest's sake we'd suggest looking at Orion, Taurus and over towards Jupiter. Be patient and hopefully you'll be rewarded with a beautiful Geminid meteor. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal Time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **bit.ly/10_easylessons** for our 10-step guide to getting started and **bit.ly/buy_scope** for advice on choosing a scope

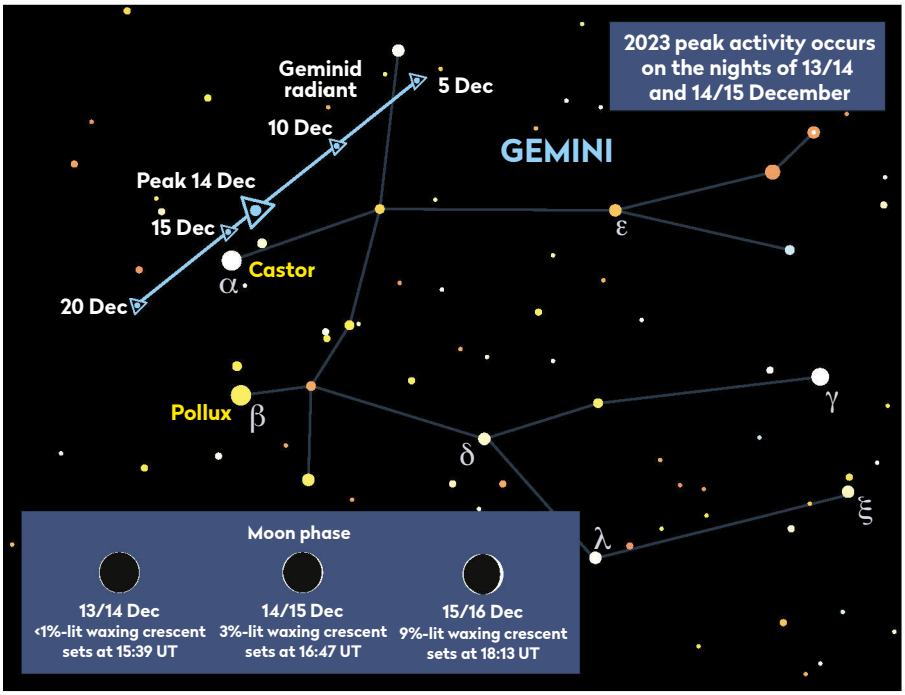
THE BIG THREE

The top sights to observe or image this month

DON'T MISS

The Geminid meteor shower at its peak

BEST TIME TO SEE: 10–16 December



▲ The timing of the Moon's phases couldn't be better for the peak of this year's Geminids – a new Moon means you'll have several long, dark nights in which to spot them

The Geminid meteor shower is one of the big-hitters of the year. This is because it has a high peak Zenithal Hourly Rate (ZHR) and a relatively broad peak period. If the Moon is out of the way, the weather kind, and you have dark skies, the Geminids can be awesome. This year, the Moon is out of the way. It's in an early phase and sets fairly early on. The unknown is the weather and during December this can be an issue.

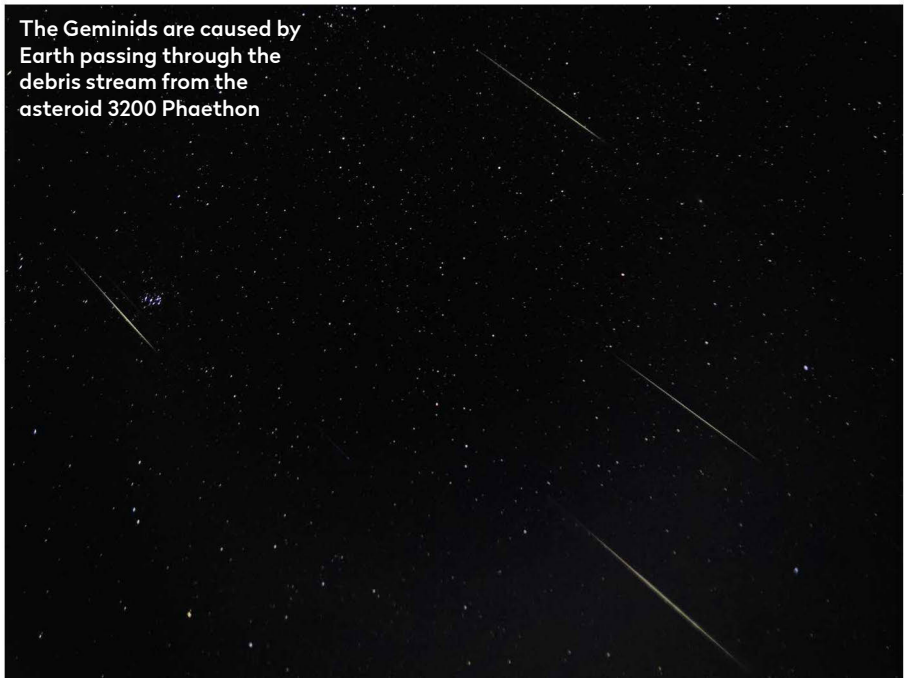
Activity starts early December, low ZHR rates producing the odd Geminid during an all-night session. Things start to get interesting after 10/11 December in the run up to the peak period. This year, peak rates should occur on the nights of 13/14 and 14/15 December. The shower's activity peters out by the end of the third week in December.

The Geminid radiant (the location where meteors appear to emanate from) barely dips below the horizon mid-afternoon, meaning that shower meteors could, in theory, be seen as darkness falls. However, bear in mind that the radiant altitude is very low early on and this will significantly reduce the number of meteors seen.

The good news is the radiant increases to a maximum altitude of 70° at around 02:20 UT. With the Moon out of the way and clear skies, there's potential for around 12 hours of meteor watching. Sleep management and warm clothing are a must for serious Geminid watchers!

The best strategy is to wrap up warm and use something like a sun-lounger to lie on. View at an altitude around 60°, this being where there's a balance between atmospheric extinction – dimming of meteors due to a thicker atmospheric layer – and a thick enough section of atmosphere for meteors to occur in. Directly overhead represents the thinnest layer of atmosphere you can look through. In theory this would give the cleanest view, but at the cost of a reduced number of meteors.

Aim to keep watch in shifts, with comfort breaks in between. A flask of hot tea or soup can really take the sting out of a long, cold December Geminid watch. Give yourself at least 20 minutes in total darkness to properly dark adapt and don't expose your eyes to any stray light throughout the watch. If you must use light to write an observation or access a chart, use a dim red torch.



The Geminids are caused by Earth passing through the debris stream from the asteroid 3200 Phaethon

ALL PICTURES: PETE LAWRENCE

Mare Orientale region

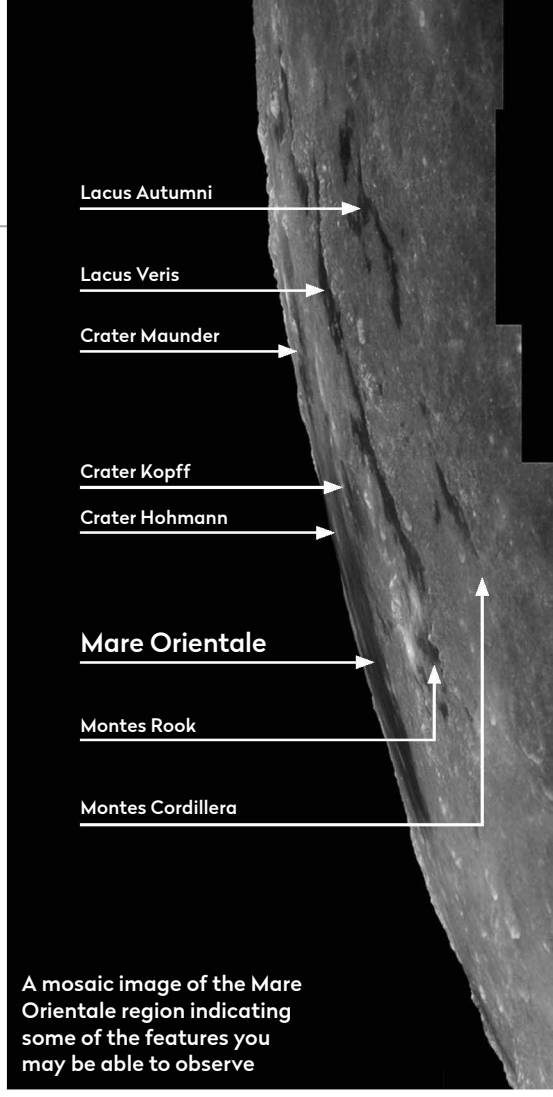
BEST TIME TO SEE: Mornings of 9–12 December

Mare Orientale is the name given to a 300km-diameter lunar sea very close to the Moon's southwest limb as seen from Earth. The Orientale basin comprises the sea plus a series of concentric mountain ranges, the outermost of which has a diameter of 920km. Seen from above, the central Mare Orientale plus its surrounding mountain rings appear like a giant bull's eye. Smaller patches of dark lava fill in some areas between the concentric ranges.

The Moon presents us with the same familiar face, but orbital effects cause it to appear to rock and roll slightly over time. These effects are collectively called libration and for features such as Orientale on the Moon's edge, libration can either hide them from us or give us a better view.

On 9 December it's an improved view that we get as libration moves Orientale and its surroundings into an Earth-friendly position. It's a tricky feature to decode as its structures appear heavily foreshortened, but you should be able to make out some of the eastern peaks of the outer Montes Cordillera, as well as peaks of the inner Montes Rook range. Also look out for some of the darker lava patches. The larger examples have been given names such as Lacus Veris and Lacus Autumni.

Libration favours the region as the evening terminator approaches on the mornings of 9, 10, 11 and possibly 12 December, although the phase will be very slim at just 1.6% on the morning of 12 December. The holy grail here is to try to see the inner lava of Mare Orientale itself. During December the mare may be glimpsed, but it will appear right on the Moon's edge. Consequently, don't expect Mare Orientale to be an easy catch!



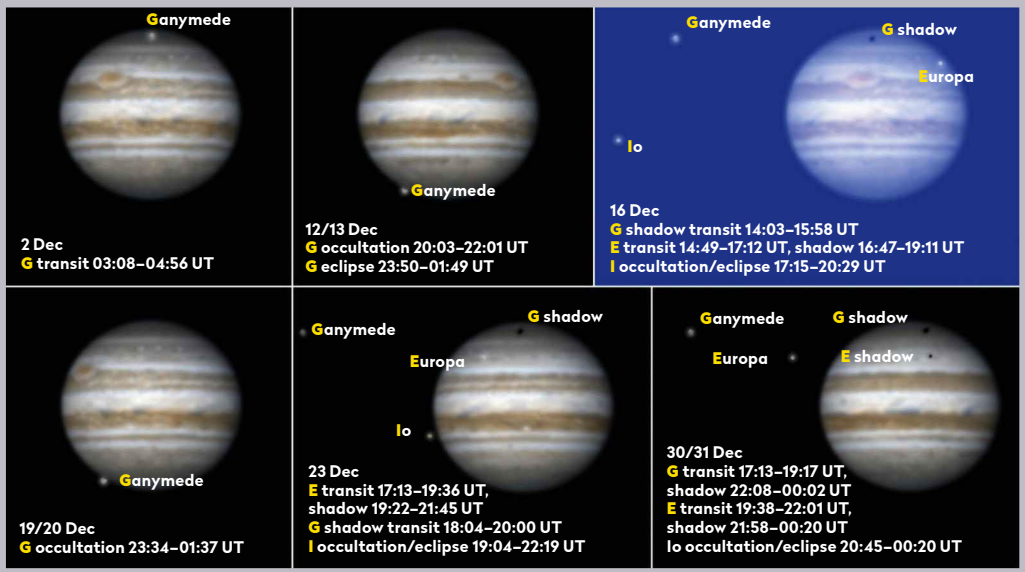
A mosaic image of the Mare Orientale region indicating some of the features you may be able to observe

Ganymede events

BEST TIME TO SEE: As shown

Jupiter's giant moon Ganymede will be involved in a number of interesting events this month. Being so large and casting such a huge shadow on Jupiter's atmosphere, these should be relatively easy to see using a small scope.

We start with Ganymede transiting the planet from 03:08 to 04:56 UT on 2 December. The start of this transit occurs with Jupiter at 17° altitude, but the end occurs as the planet is setting. A better-timed event is on 12 December when Ganymede is occulted by Jupiter between 20:03 and 21:41 UT. After reappearance, Ganymede has a brief respite before succumbing to being eclipsed by Jupiter's shadow between 23:50 UT on 12 December and 01:49 UT on 13 December. On 16 December, Ganymede's shadow transits the planet during daylight from 14:03 until 15:58 UT. Ganymede is once again occulted by Jupiter between 23:34 UT on the 19th and 01:37 UT on 20 December. On 23 December, Ganymede's shadow can be seen in transit from 18:04 to 20:00 UT. Finally, on the 30th, Ganymede transits from 17:13 to 19:17 UT, its shadow appearing for a double shadow transit with Europa's shadow between 22:08 and 00:02 UT.



▲ Some highlights of Ganymede's interactions with Jupiter that are visible this month

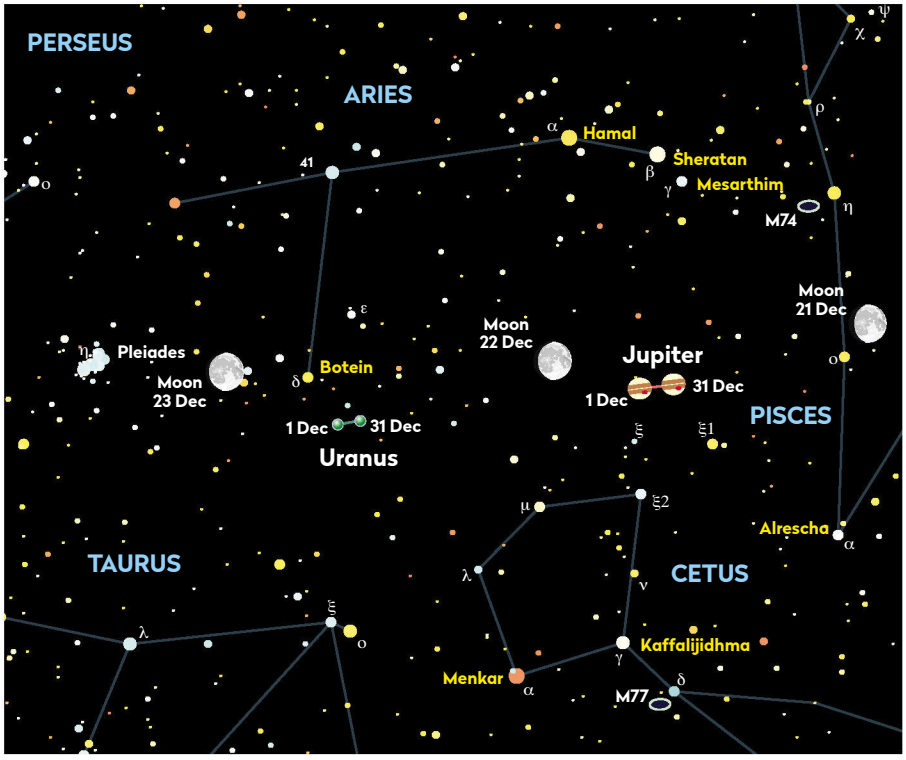
THE PLANETS

Our celestial neighbourhood in December

PICK OF THE MONTH

Uranus

Best time to see: 1 December, 22:40 UT
Altitude: 54°
Location: Aries
Direction: South
Features: Weak banding, colour, brighter moons
Recommended equipment: 200mm or larger



▲ **Where to find Uranus this month. The star Botein (Delta Arietis) will help you locate it**

PETE LAWRENCE X 2

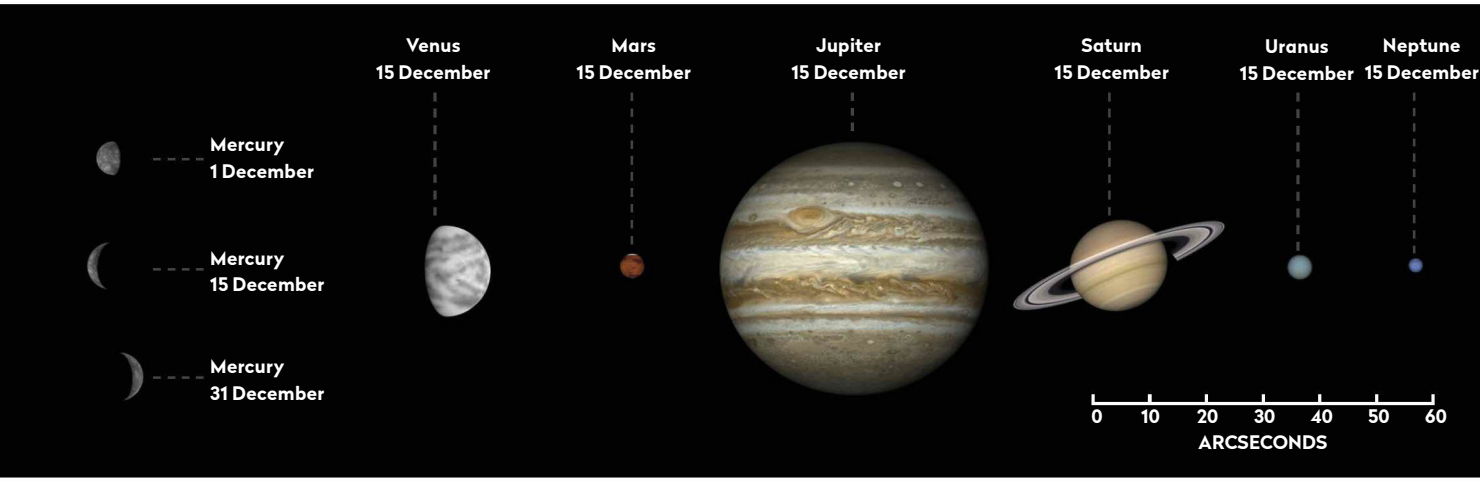
Uranus is really well placed for viewing at the moment, having reached opposition in the middle of last month. It's able to attain a maximum altitude of 54° under truly dark skies as seen from the centre of the UK, maintaining this capability all month long. It's currently shining at mag. +5.6 and located less than 3° south of mag. +4.3 Botein (Delta (δ) Arietis).

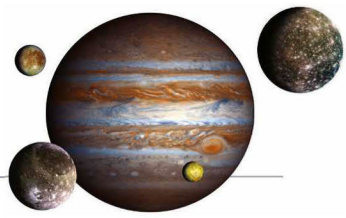
Botein is a great navigational tool for finding Uranus. Using average binoculars (7x50), locate and place Botein at the centre of the field of view. This should position mag. +4.6 Epsilon (ε) Arietis near the edge of the field. Look roughly one-third of the Botein-to-Epsilon distance from Botein in a southwest direction to locate mag. +6.2 54 Arietis. Move a similar distance south of 54 Arietis to locate mag. +6.1 53 Arietis. Being just half a degree fainter than Uranus, both stars are good candidates for confusion, but identified correctly they work well for locating the planet. At the start of December, Uranus is located east-southeast of 53 Arietis. Moving slowly west-southwest, Uranus ends the month in line with 54 and 53 Arietis.

The appearance of this distant world doesn't change dramatically over time. On 1 December Uranus shines at mag. +5.6 and presents a 3.8-arcsecond disc, this degrading to mag. +5.7 with a 3.7-arcsecond disc by the end of the month – hardly any change. A small telescope will show its greenish hue as well as the fact that it presents a disc. Imaging under good seeing conditions may reveal subtle bands on the planet's globe. Extended exposures at high image scale may possibly reveal Uranus's brighter moons. Just be careful not to over-expose the planet too much, as that may hide them.

The planets in December

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see:
31 December, 1 hour before sunrise
Altitude: 3° (very low)
Location: Ophiuchus
Direction: Southeast
Mercury reaches greatest eastern elongation on 4 December, separated from the Sun by around 21°. Shining at mag. –0.3 on this date, Mercury sets just over an hour after sunset. Despite an improving position, fading brightness towards the middle of the month means Mercury becomes harder to see. Inferior conjunction occurs on 22 December, after which Mercury re-emerges into the morning sky rapidly. However, it's dim as it does so, your best chance of spotting it being on 31 December when, shining at mag. +0.8, the planet rises 90 minutes before sunrise.

Venus

Best time to see:
1 December, 05:55 UT
Altitude: 16°
Location: Virgo
Direction: Southeast
Venus is a dominant morning object. On 1 December, shining at mag. –4.1, it rises fractionally over 4 hours before the Sun, giving 2 hours to appreciate it against astronomically dark skies. At the start of the month, mag. +1.0 Spica (Alpha (α) Virginis) lies 4.5° southwest of Venus. At the start of December, Venus shows a 67%-lit, 17-arcsecond disc through the eyepiece, values which change to 77%-lit and 14 arcseconds across by 31 December. By the end of the month, Venus rises 3 hours and 10 minutes before the Sun. The Moon appears close on 9 December.

Mars

Not visible this month.

Jupiter

Best time to see:
1 December, 21:50 UT
Altitude: 50°
Location: Aries
Direction: South
Jupiter is a beautifully placed evening planet. Shining at mag. –2.7 at the start of December and –2.5 at the end of the month, it appears 50° up when due south as seen from the centre of the UK. A bright gibbous Moon is nearby on the evenings of 21 and 22 December.

Saturn

Best time to see:
1 December, 17:45 UT
Altitude: 24°
Location: Aquarius
Direction: South
Saturn is reasonably well placed at the start of December, visible at its highest altitude, due south, under almost true dark-sky conditions. However, by New Year's Eve Saturn's peak altitude occurs when the Sun is still above the horizon. Through the eyepiece, Saturn's north pole appears tilted towards Earth by around 10°. A 28%-lit waxing crescent Moon sits 3.8° south-southwest of Saturn on the evening of 17 December, closest as the pair approach setting around 21:00 UT.

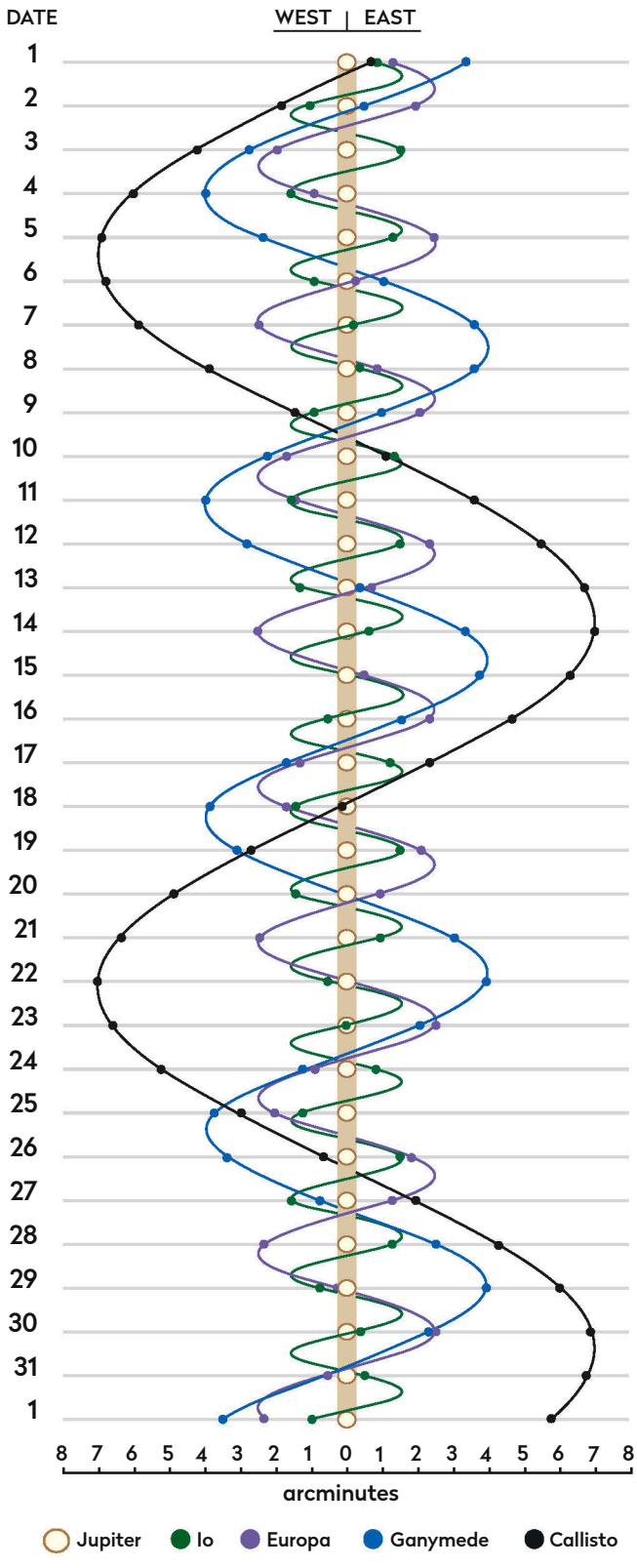
Neptune

Best time to see:
1 December, 19:13 UT
Altitude: 34°
Location: Pisces
Direction: South
Neptune is an evening planet, well-placed and at mag. +7.9 at the start of December, but deteriorating slightly towards the end of the month.

MORE **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: DECEMBER

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically over the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – DECEMBER

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- COMPASS AND FIELD OF VIEW
- MILKY WAY

When to use this chart

1 December at 00:00 UT
15 December at 23:00 UT
31 December at 22:00 UT

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in December*

Date	Sunrise	Sunset
1 Dec 2023	08:02 UT	15:55 UT
11 Dec 2023	08:15 UT	15:50 UT
21 Dec 2023	08:23 UT	15:52 UT
31 Dec 2023	08:26 UT	15:59 UT

Moonrise in December*

Moonrise times

1 Dec 2023, 19:16 UT	17 Dec 2023, 12:02 UT
5 Dec 2023, --:-- UT	21 Dec 2023, 12:46 UT
9 Dec 2023, 03:59 UT	25 Dec 2023, 14:03 UT
13 Dec 2023, 09:30 UT	29 Dec 2023, 18:14 UT

*Times correct for the centre of the UK

Lunar phases in December

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
				1	2	3
4	5	6	7	8	9	10
11	12 NEW MOON	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27 FULL MOON	28	29	30	31

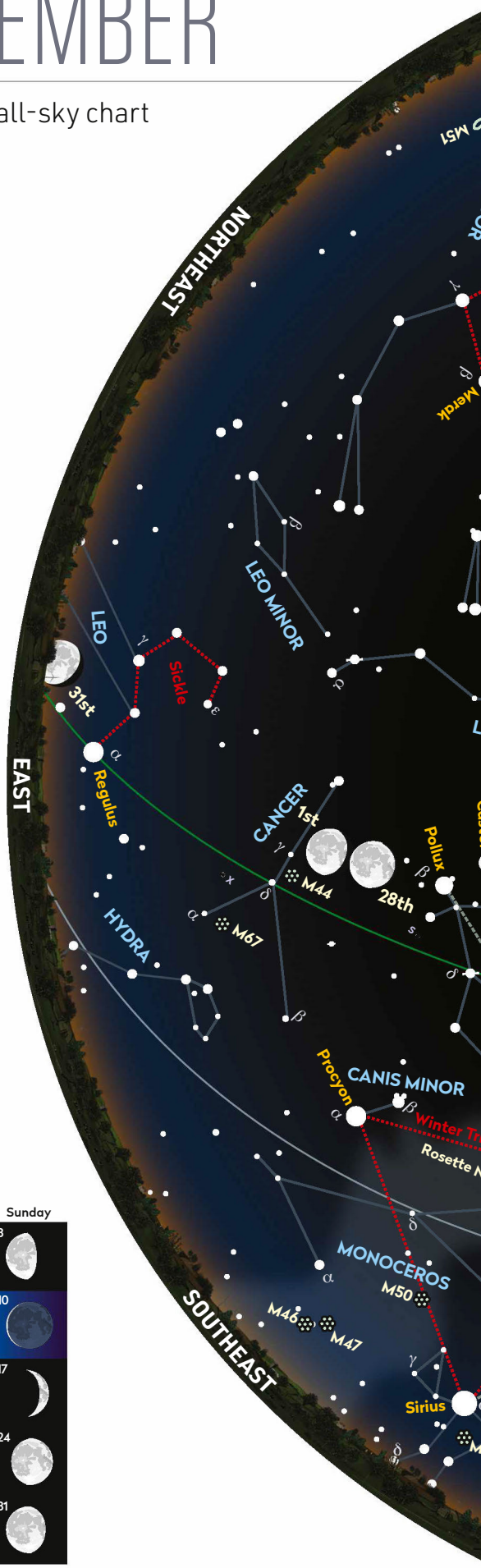


CHART: PETE LAWRENCE

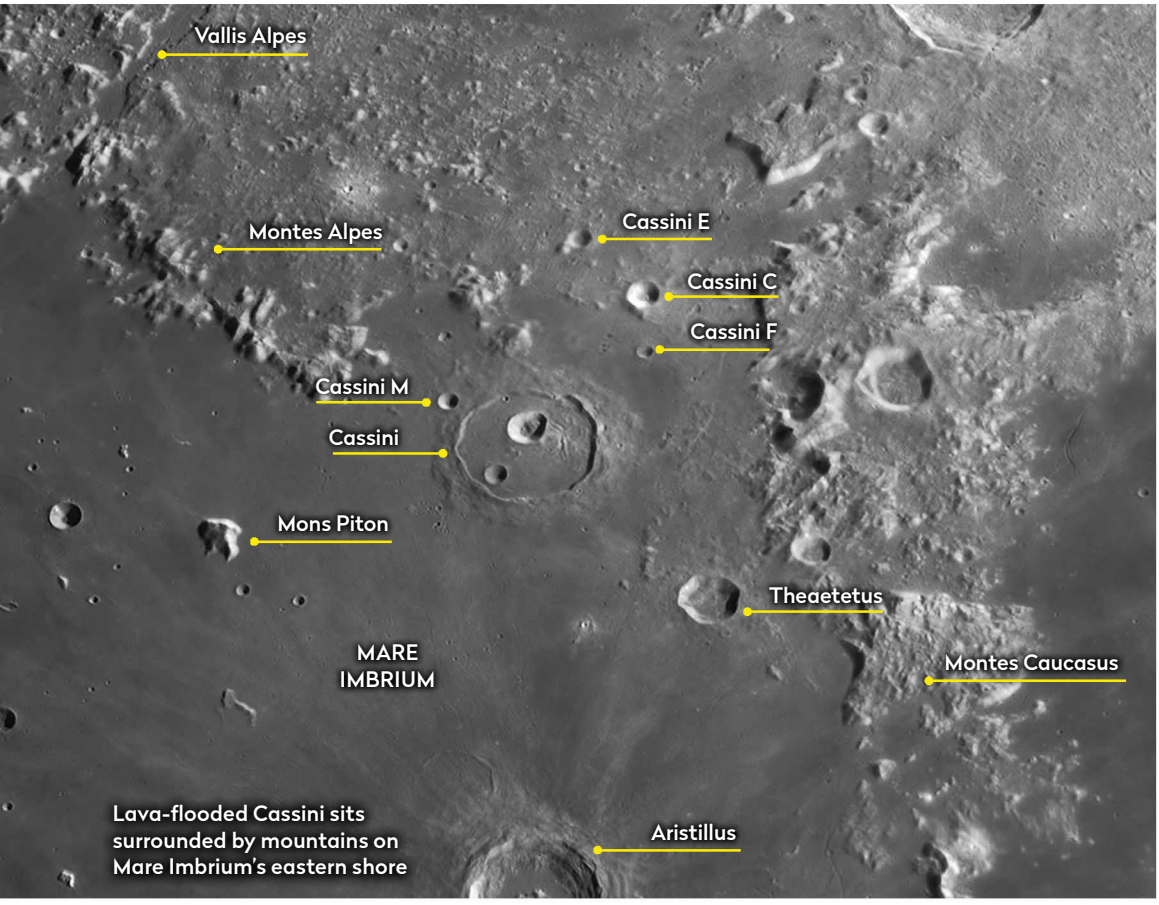
MORE **ONLINE**

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

MOONWATCH

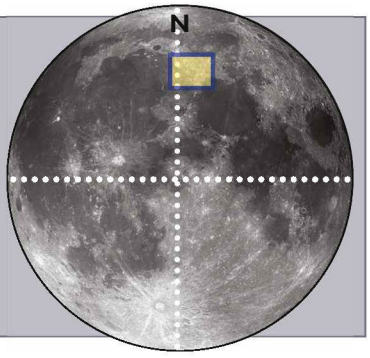
December's top lunar feature to observe



Lava-flooded Cassini sits surrounded by mountains on Mare Imbrium's eastern shore

Cassini

Type: Crater
Size: 58km
Longitude/latitude: 4.7° E, 40.3° N
Age: 3.8–3.9 billion years
Best time to see: First quarter (19 December) or six days after full Moon (4 December and 3 January)
Minimum equipment: 50mm refractor



Cassini is an example of a ring plain crater, a narrow rim enclosing a relatively flat floor area (aside from some obvious exceptions). The rim is complete all the way round and rises to around 1.2km high, decreasing to 460m on the eastern side. The whole structure is surrounded by a rather impressive ejecta rampart, a very obvious feature as Cassini sits on the flat northeast lava surface of 1,250km **Mare Imbrium**.

The most prominent of those 'obvious exceptions' on Cassini's flat floor is the elongated form of the 17km bowl-shaped crater **Cassini A**, its linear size being 29 per cent that of Cassini itself. The crater appears mostly circular, but with an obvious extension to the east creating a pear shape. The floor of Cassini A appears to contain a series of narrow ridges. The lunar observers Percy Wilkins and Patrick Moore, using the 33-inch Meudon refractor in Paris on 3 April 1952, describe how the base of Cassini has a "white, very shallow crater within which is a most minute central pit". As a result, they proposed calling the feature the Washbowl, an informal name that some amateurs continue to use today. Modern analysis of the feature suggests it's not a crater at all, but possibly a trick of the light when the original observation was made. Cassini A is also notable because of the grooves that can be seen within the hilly area to the east and southeast of it. These are fascinating to observe when light falls obliquely on Cassini.

Another 'obvious exception' comes in the form of 9.4km **Cassini B**. Unlike Cassini A, Cassini B really does have the appearance of a circular crater and also has the classic bowl-shape. It sits close to Cassini's southwest rim. Under oblique lighting it should be possible to detect the presence of three hills located between Cassini A and B. There's a third 2.4km craterlet present on Cassini's floor, located further north, that appears to be touching Cassini's northern rim.

Looking at the bigger picture, Cassini is fortuitously positioned in a relatively flat area between **Montes Alpes** to the northwest and **Montes Caucasus** to the southeast. These dramatic ranges provide excellent framing for the crater. Many of the smaller craters to the east are designated satellites of Cassini, the most notable being 13.8km **Cassini C** which originally had its own name, being known as Zinger. The International Astronomical Union (IAU) relocated that name to a far-side crater, now known as Tsinger.

Heading west across the flat lava of Mare Imbrium, it's not mountain ranges that dominate but rather a singular mountain called **Mons Piton**. This is best seen like Cassini, at first quarter or six days after full Moon and is most impressive. Its form can be contained within a circle of 25km diameter, the mountain peak rising to a height of 2.25km. Its most impressive trick is to create a dramatic pointed shadow that is beautifully projected across Imbrium's floor when the morning or evening Sun is low in the mountain's sky.

COMETS AND ASTEROIDS

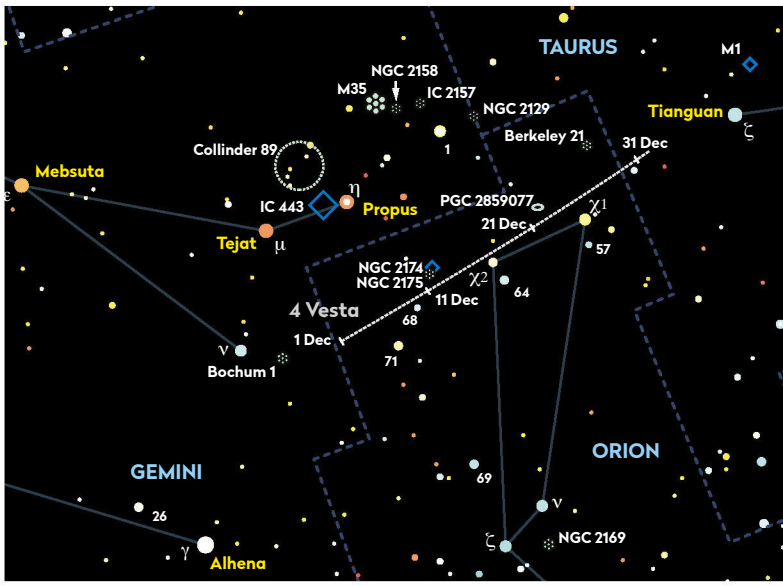
Swing your binoculars to 4 Vesta, the second-largest body in the asteroid belt

Minor planet 4 Vesta reaches opposition on 21 December when it can be found shining at mag. +6.6 among the stars of northern Orion. To fit within the IAU defined boundary of northern Orion is quite a feat, as this portion of the constellation, the bit north of his club and beneath the foot of the twin Castor in Gemini, is only 7.4° wide. Vesta manages to stay within this boundary until 29 December when it slips slightly across the border into Taurus.

Vesta begins the month 3.1° south-southwest of mag. +2.8 Tejat (Mu (μ) Geminorum). From here it tracks west and slightly north to pass just north of mag. +5.8 68 Orionis on 8 and 9 December, mag. +4.6 Chi^2 (χ^2) Orionis on 16/17 December and mag. +4.4 Chi^1 (χ^1) Orionis on 24 and 25 December.

At the start of the month it appears at magnitude +7.2, brightening to +6.6 at opposition on 21 December before dimming slightly to +6.8 on New Year's Eve. This places Vesta squarely within range of binoculars and a small telescope is an ideal instrument to keep track of it.

Vesta was discovered on 29 March 1807 by Wilhelm Olbers and was the fourth minor planet discovered. It's a large object with a mean diameter of 525km. In the realm of the minor planets, only 1 Ceres is larger with an average diameter of 939km. Under modern classification, 1 Ceres is a dwarf planet. Vesta completes one orbit around the Sun every 3.63 years, its orbital path taking it out as far as 2.57 AU from the Sun and in as close as 2.15 AU. During a poor opposition, Vesta may only reach mag. +8.5, but at a good opposition it may become a naked-eye object, shining at mag. +5.1. Interestingly, its size combined with its varying distance from Earth means it presents an angular diameter which varies between 0.2 and 0.7 arcseconds.



▲ **Giant asteroid Vesta sails over Orion's club during December**

STAR OF THE MONTH

Arneb, the lavatorial star on the back of the Hare

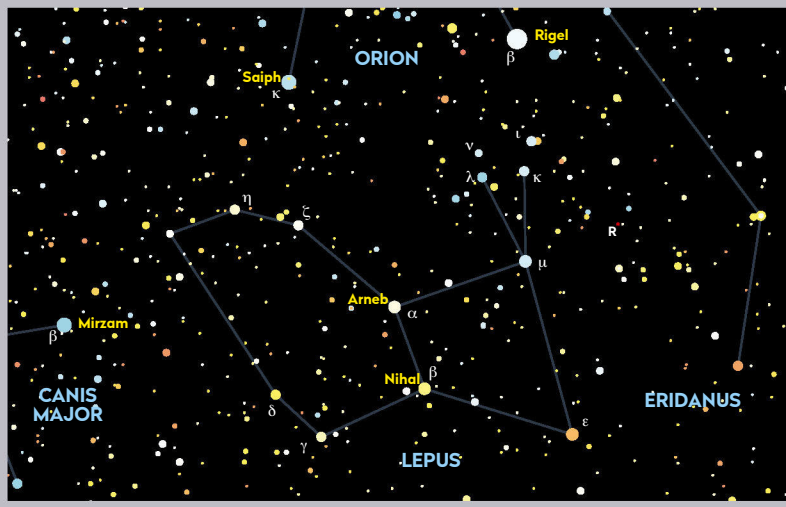
Lepus the Hare is a small constellation to the south of Orion the Hunter, the prey for Orion and his two dogs, Canis Major and Canis Minor. A crude description of Lepus is that it looks like the symbol for infinity (∞) with ears. The 'pinch point' in the centre of the symbol is represented by Arneb (Alpha (α) Leporis) and Nihal (Beta (β) Leporis).

Arneb, its name derived from the Arabic for 'hare', shines at mag. +2.6, slightly brighter than mag. +2.8 Nihal to its south. In Chinese it is one star of an asterism formed from Alpha, Beta (β), Gamma (γ) and Delta (δ) Leporis called Cè, which means 'toilet'. Alpha is known as 'Cè yī', 'the first star of toilet'.

Arneb's subtle appearance beneath mighty and dominant Orion disguises the fact that it's an impressive star. It's estimated to be around 2,200 lightyears distant and this means it must be pretty bright. Its absolute magnitude is –6.57, which is how bright it would appear at a standard distance of 10 parsecs (32.6 lightyears). For comparison, the Sun's absolute magnitude is +4.83.

Arneb is 13.9 times more massive, 75 times larger and a staggering 12,000 times more luminous than the Sun. Its spectral classification is F0 Ib, which indicates it's a yellow-white (F0) less luminous supergiant (Ib). There's some conjecture about how evolved the star is, some sources believing it has passed the supergiant phase. Its mass also suggests it'll end its days as a spectacular supernova.

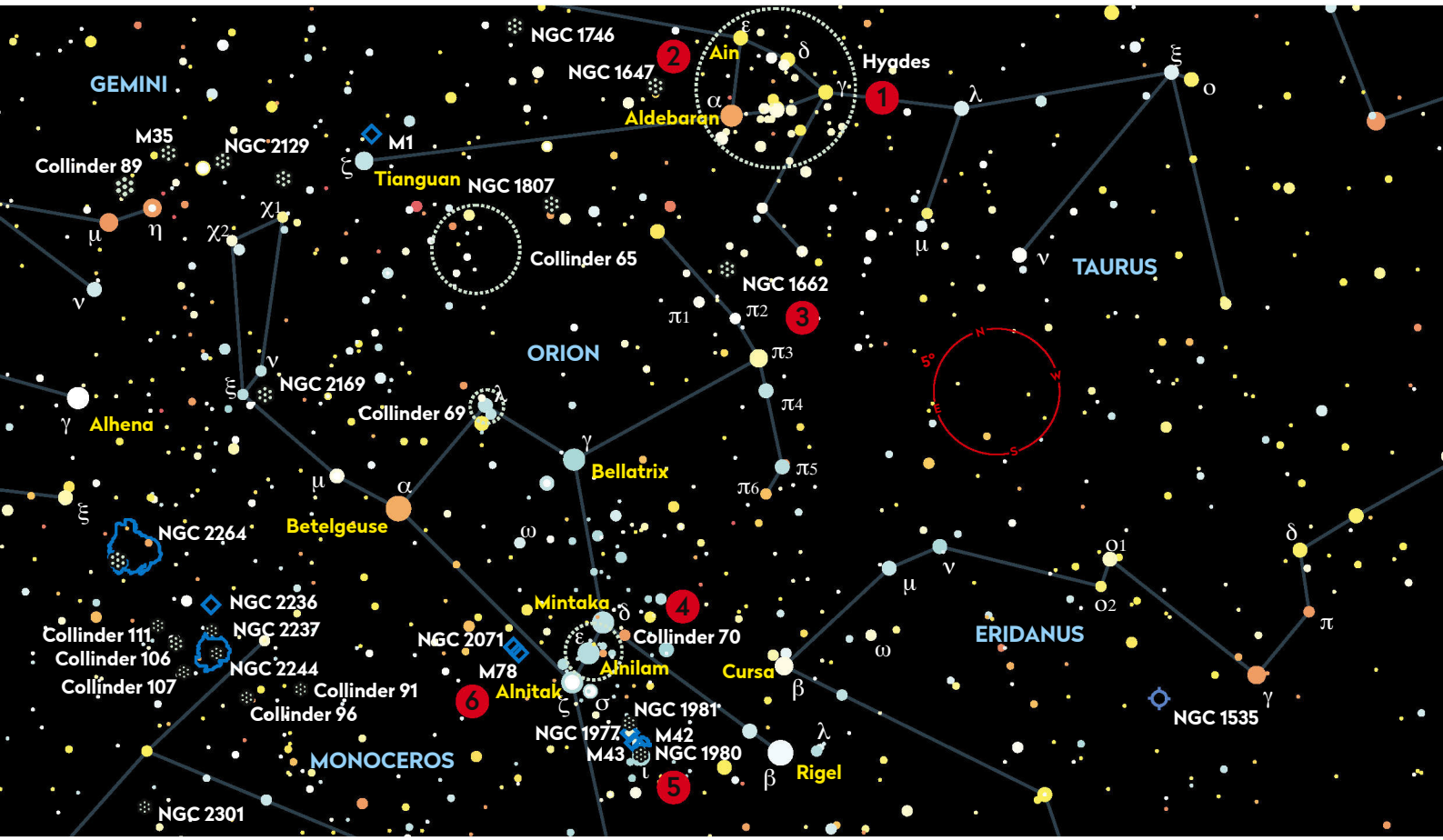
▼ **In Chinese astronomy, Arneb is part of a constellation that forms a toilet**



BINOCULAR TOUR

With Steve Tonkin

From star-packed clusters and winter favourites to a real test of your averted vision



1. The Hyades

10x50 The Hyades cluster is next to mag. +1.0 Aldebaran (Alpha (α) Tauri), the reddish eye of the Bull, which is not part of the cluster but a foreground star. The cluster is only 153 lightyears away, making it the nearest open cluster to us. In mythology, the Hyades were the daughters of Atlas, and their weeping for their brother Hyas, who was slain by a lion, is the rain that is associated with their heliacal setting in spring. ☐ **SEEN IT**

2. NGC 1647

10x50 About 3° northeast of Aldebaran is a lovely little cluster, NGC 1647, often ignored because of the presence of its more prominent neighbour. With 10x50s you should be able to see eight or nine stars against a background glow about one and a half times the apparent size of the Moon. It's actually twice the size of the Hyades, but nearly 12 times the distance, which is why it seems so small in comparison. ☐ **SEEN IT**

3. NGC 1662

15x70 Switch to larger binoculars for our next target, 6.25° from Aldebaran in the direction of mag. +0.3 Rigel (Beta (β) Orionis). In 15x70 binoculars, NGC 1662 appears as a complex winding string of stars against an elliptical background glow. With a core of about 10 lightyears diameter, it's approximately the same size as the Hyades, but is nearly 10 times as far away. ☐ **SEEN IT**

4. Collinder 70

10x50 Most amateur astronomers have seen Collinder 70 without realising it: it's the oval-shaped group of very young bluish-white stars that surrounds the Belt stars of Orion. On a clear night, you should be able to see at least 70 stars in this magnificent cluster. They form some beautiful curved chains, in particular the S-shaped chain that weaves its way between mag. +1.8 Alnilam (Epsilon (ε) Orionis) and mag. +2.4 Mintaka (Delta (δ) Orionis). ☐ **SEEN IT**

5. The Great Nebula in Orion

10x50 The Great Orion Nebula, M42, is a highlight of the winter skies and a superb object in binoculars of any size. It's the nearest stellar nursery to Earth and is visible to the naked eye as the fuzzy central 'star' of Orion's Sword. It is extremely sensitive to sky transparency and is best observed soon after rain has cleaned the sky of dust, revealing its exquisite, intricate detail. ☐ **SEEN IT**

6. M78

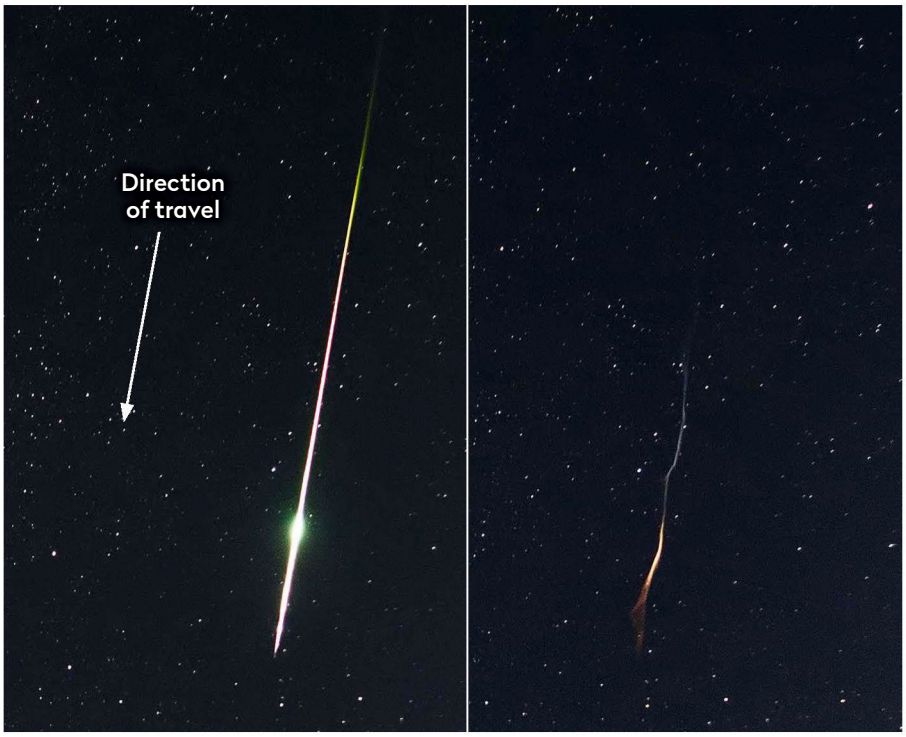
15x70 This demands mounted binoculars, a very transparent sky and averted vision. Put mag. +1.9 Alnitak (Zeta (ζ) Orionis) just outside the south-southwest of the field of view and a small misty glow should appear near the centre. Brighter at the top than at the bottom, it looks like a comet, showing why Charles Messier put it in his catalogue of objects for comet-hunters to ignore. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Your challenge this month is not just to spot a meteor, but to capture its train



▲ A bright meteor trail (left) flares towards the end of its track, an event which results in a bright, sinewy meteor train (right) caused by ionised gas lingering in the atmosphere

Most of us have seen a meteor trail at one time or another, the rapid streak of light caused when a small, typically sand-grain-sized particle vaporises in Earth's atmosphere. If you haven't caught one yet, December is a good time to try as it hosts the peak of arguably the best meteor shower of the year, the Geminids. This month's challenge is to try to observe a phenomenon associated with bright trails: a meteor train.

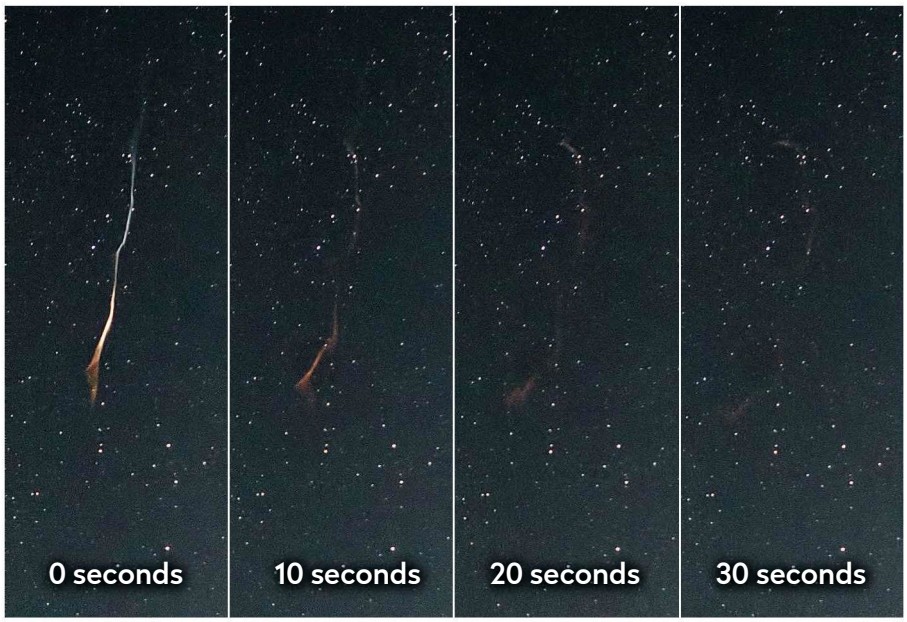
The Geminid shower is active from 4 to 17 December, with heightened activity from the 9th to the 16th. It peaks on the evening of 14 December, meriting all-night watches on the nights of 12/13, 13/14 and 14/15 December. If it's clear and you attempt this, you'd be very unlucky not to see meteor trails.

Sometimes the vaporising particle or meteroid is larger than average and produces a brighter trail. The International Astronomical Union (IAU) defines a meteor brighter than mag. –4 as a fireball, and if you're lucky enough to catch one of these it's a sight not quickly forgotten.

Brighter events can also be accompanied by what's known as a meteor train. A train arises when the column of ionised gas left behind by a bright trail event is large enough and bright enough to remain visible after the trail has subsided.

Often incorrectly described as a 'smoke trail', a meteor train initially appears like a ghostly aircraft vapor trail. If you see one, the way to record the phenomenon visually is to count for how many seconds it remains visible. Combined with an accurate assessment of the magnitude of the initial trail, the duration provides excellent data correlating train visibility to trail brightness.

The train fades over time but a persistent one may appear to distort and break up before it disappears. This is caused by high-altitude atmospheric wind. If you're attempting to photograph meteor trails by taking consecutive exposures during the night, on capturing a bright one look at the following frames very carefully. If your exposure time is short enough, you might catch the train as it distorts and disperses. If you are using long exposures, say over 20 seconds, the train's definition may become blurred as it distorts and detail may be lost. The best strategy is to use a fast, wide-angle lens, a mid to high ISO and relatively short exposure times. A high-sensitivity video system is particularly good for this type of capture. As ever, if you do manage to record any trails or trains, make sure your results are correctly time- and date-stamped to make them useful.



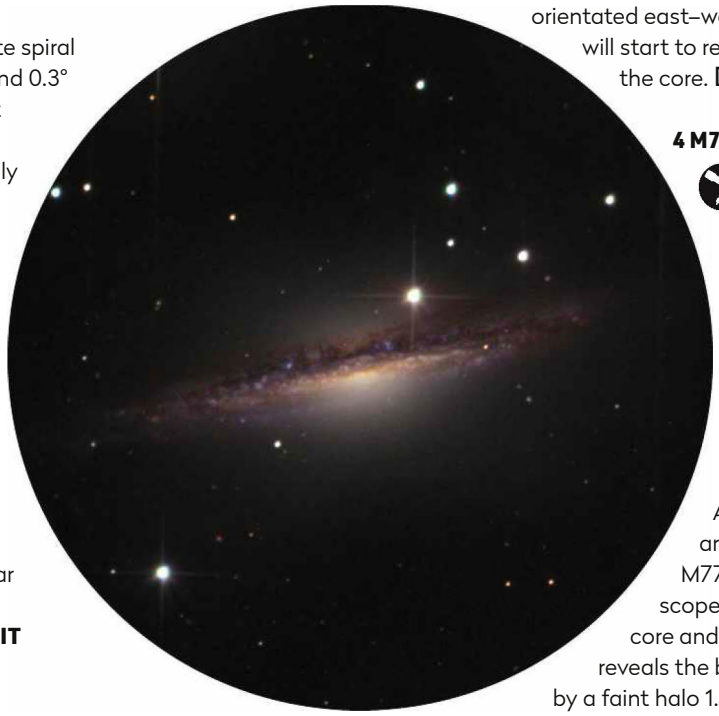
▲ Frequent short exposures with a wide-angle lens will capture the train as it distorts and fades. You might get lucky – exceptional trains have been observed persisting for minutes

DEEP-SKY TOUR

A look around Cetus the Whale for galaxies, more galaxies and a fascinating pulsating star

1 NGC 864

NGC 864 is an intermediate spiral galaxy located 5.1° west and 0.3° north of mag. +4.8 Nu (ν) Ceti. It shines with an integrated magnitude of +11.0 but is virtually face-on to us, so its surface brightness is low. Light-polluted or less than pristine skies will hide it well, as will a lack of dark adaptation. Its inner core appears 2 x 1.5 arcminutes across, but the outer halo in which the galaxy's spiral arms are located is very faint. A 250mm scope will show the galaxy as a faint glow, the most obvious feature being the mag. +10.8 star TYC 0044-0304-1 just east-southeast of the core. ☐ **SEEN IT**



▲ **Stunning edge-on galaxy NGC 1055 is our third target. Can you discern the different shapes of the five galaxies in this month's tour?**

2 NGC 936

Head 7.7° east-southeast of NGC 864 to locate NGC 936. Alternatively, find it 1.1° west of mag. +5.3 75 Ceti. NGC 936 is a barred lenticular galaxy, 60 million lightyears from the Sun. It shines with an integrated magnitude of +10.2 and, thanks to a concentration of brightness within its core region, has a reasonable surface brightness. A 150mm scope shows a 1.5-arcminute object with a bright inner core. A 250mm scope or larger using high magnification will show the core as three patches. Long-exposure photographs reveal a brighter centre with two glowing blobs either side, the overall appearance resembling a *Star Wars* TIE fighter heading towards you. As a result, this object has been nicknamed Darth Vader's Galaxy. ☐ **SEEN IT**

3 NGC 1055

To find this edge-on spiral galaxy, head 4.9° east-northeast to a location 0.6° east and fractionally north of mag. +4.1 Delta (δ) Ceti. Here you'll find two stars just below naked-eye visibility, mag. +6.7 HIP 12555 and +7.6 HIP 12598. NGC 1055 forms the southern apex of a south-pointing almost equilateral triangle. The galaxy is listed at mag. +10.6, but is easily visible in a small scope because of its edge-on nature. Through a 150mm scope, it's a gem, a classic needle shape measuring 4 x 1 arcminutes, orientated east–west. A 250mm scope or larger will start to reveal clumpiness in and around the core. ☐ **SEEN IT**

4 M77

Our next target lies half a degree south-southeast of NGC 1055 and 0.9° east-southeast of Delta Ceti. Messier 77 is a barred spiral galaxy around 47 million lightyears away. It's bright at mag. +8.8 and has a high surface brightness which makes it easy for smaller scopes to pick up. A mag. +10.8 star sits 1.1 arcminutes east-southeast of M77's core, and through a 150mm scope an initial view suggests the core and star look quite similar. Scrutiny reveals the bright core of M77 surrounded by a faint halo 1.5 x 1.0 arcminutes across. The core is noticeably bright through larger instruments as there's an apparent asymmetry to the outer halo. M77 is an active galaxy and the prototype of the Seyfert galaxy class, one of the two largest groups of active galaxies. ☐ **SEEN IT**

5 NGC 1087

Our penultimate target is NGC 1087, 1° to the southeast of M77. Like our first target, NGC 864, this is an intermediate spiral galaxy, having a structure between that of a barred and unbarred galaxy. NGC 1087 is a mag. +11.0 object with sufficient surface brightness to be seen with a small instrument. A 150mm scope shows it as a mottled, elliptical glow, 2 x 1 arcminutes in size. Larger apertures show the outer halo to have a ragged edge and the galaxy's 'surface' to be rather blotchy in appearance. This is a distant object estimated to be around 80 million lightyears away. ☐ **SEEN IT**

6 Mira (Omicron Ceti)

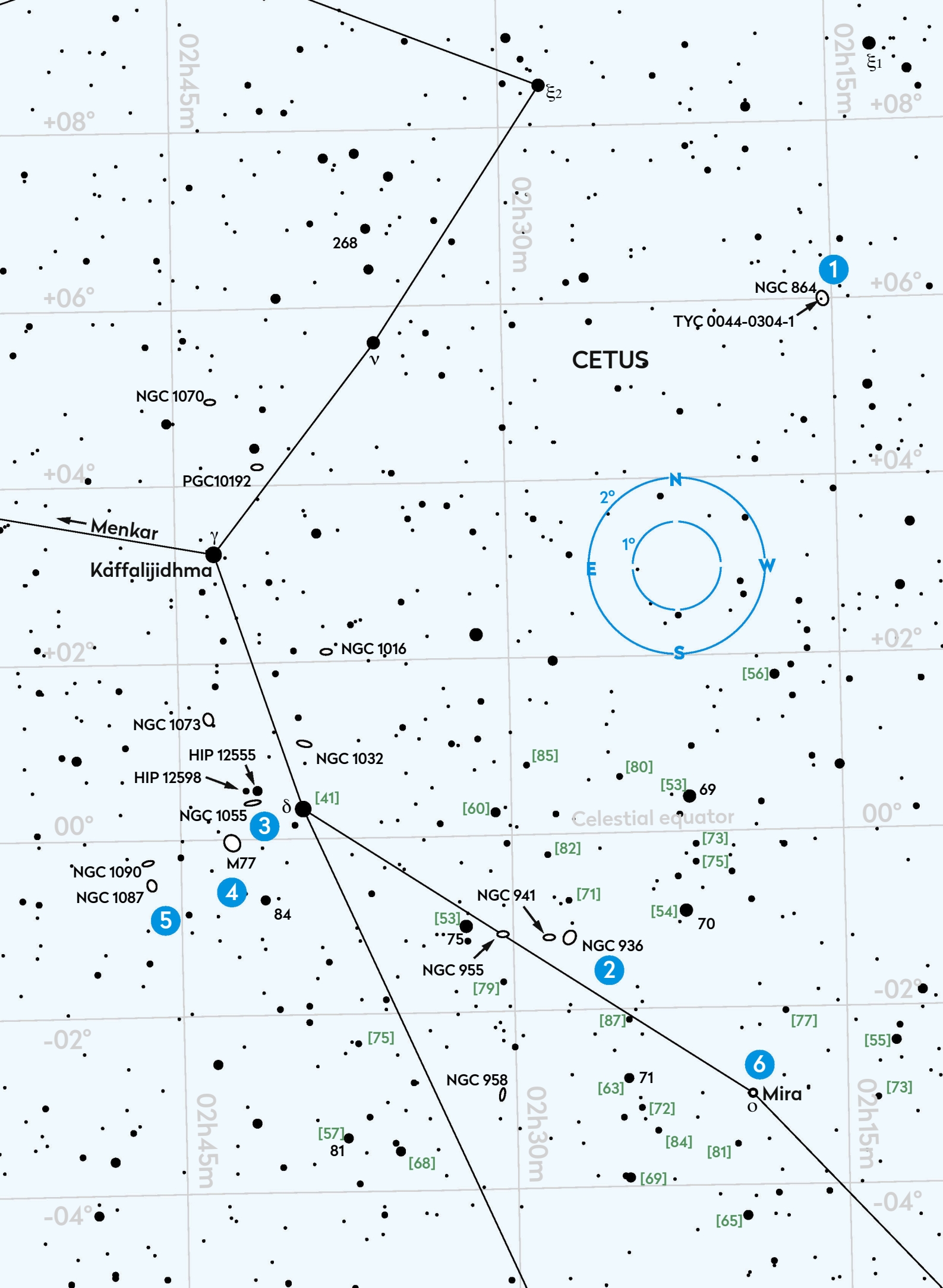
Extend a line from Menkar (Alpha (α) Ceti) through Delta Ceti a little less than the same distance again to find variable star Mira (Omicron (ο) Ceti). Mira is the prototype of the Mira class of pulsating variables and its name means 'wonderful'. It has an immense brightness range, from 10th magnitude to +2.0 (brighter than mag. +2.6 Menkar). Its average maximum is mag. +3.5, but in December 2023 it's approaching minimum. We've included some comparison star magnitudes in green on the chart, shown without the decimal point which could otherwise be mistaken for a star. For example '[75]' means mag. +7.5. ☐ **SEEN IT**

MICHAEL BREITE/STEFAN HEUTZ/WOLFGANG RIES/CCDGUIDE.COM, CHART BY PETE LAWRENCE

This Deep-Sky Tour has been automated ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

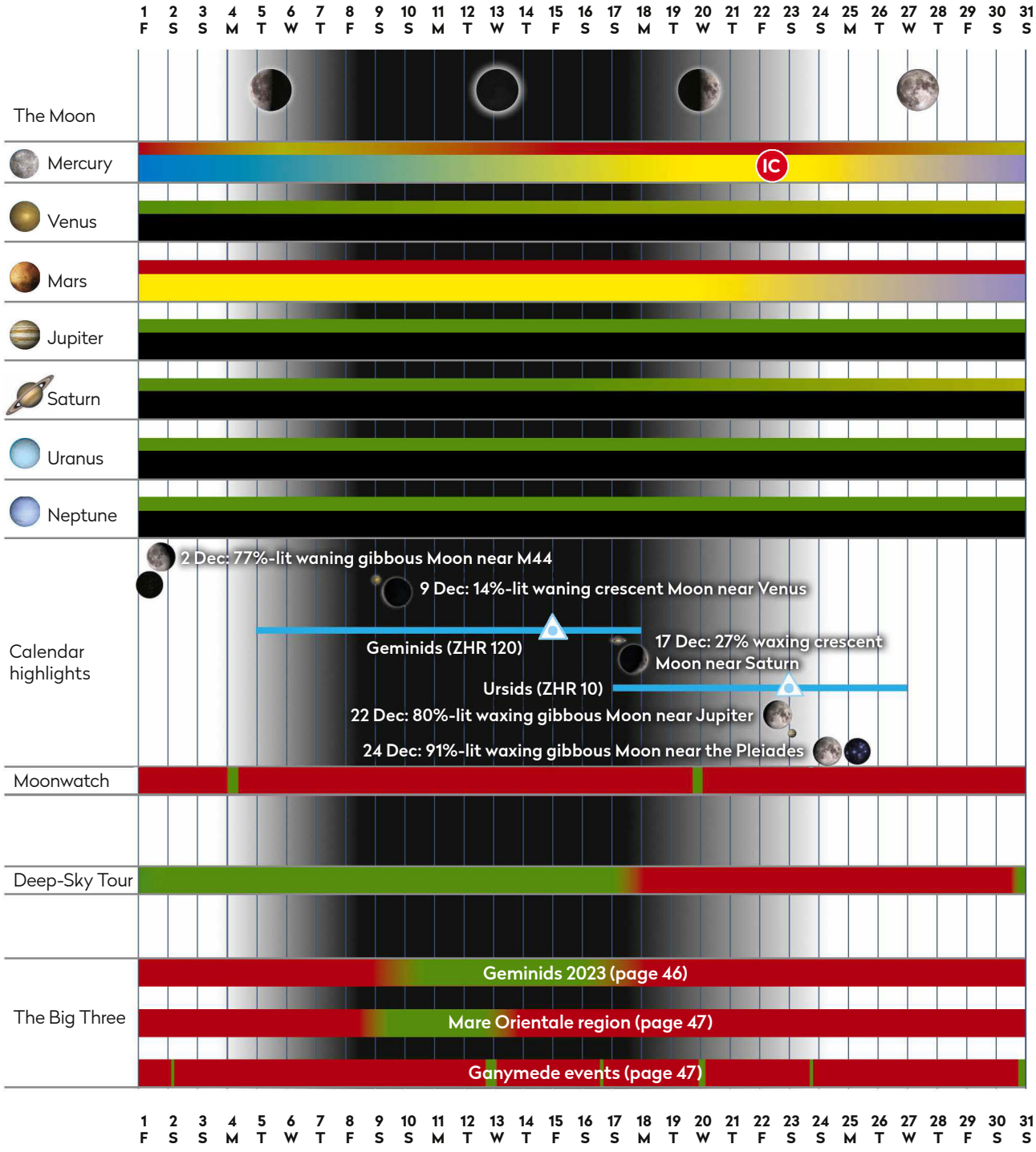
More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions


CETUS
Menkar
Kaffaljidhma
Mira
NGC 864
TYÇ 0044-0304-1
NGC 1070
PGC10192
NGC 1016
NGC 1073
NGC 1032
HIP 12555
HIP 12598
NGC 1055
M77
NGC 1090
NGC 1087
NGC 941
NGC 936
NGC 955
NGC 958
Celestial equator
N
E
W
S
2°
1°
1
2
3
4
5
6
02h45m
02h30m
02h15m
+08°
+06°
+04°
+02°
00°
-02°
-04°

AT A GLANCE

How the Sky Guide events will appear in December



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

- IC — Inferior conjunction (Mercury & Venus only)
- SC — Superior conjunction
- OP — Planet at opposition
- Meteor radiant peak
- Planets in conjunction

- Full Moon
- First quarter
- Last quarter
- New Moon

CHART BY PETE LAWRENCE

There's a lot more water on the Moon – and elsewhere in the Solar System – than most people realise

SNEZHANNA/ISTOCK/GETTY IMAGES

WATER, WATER, *everywhere?*

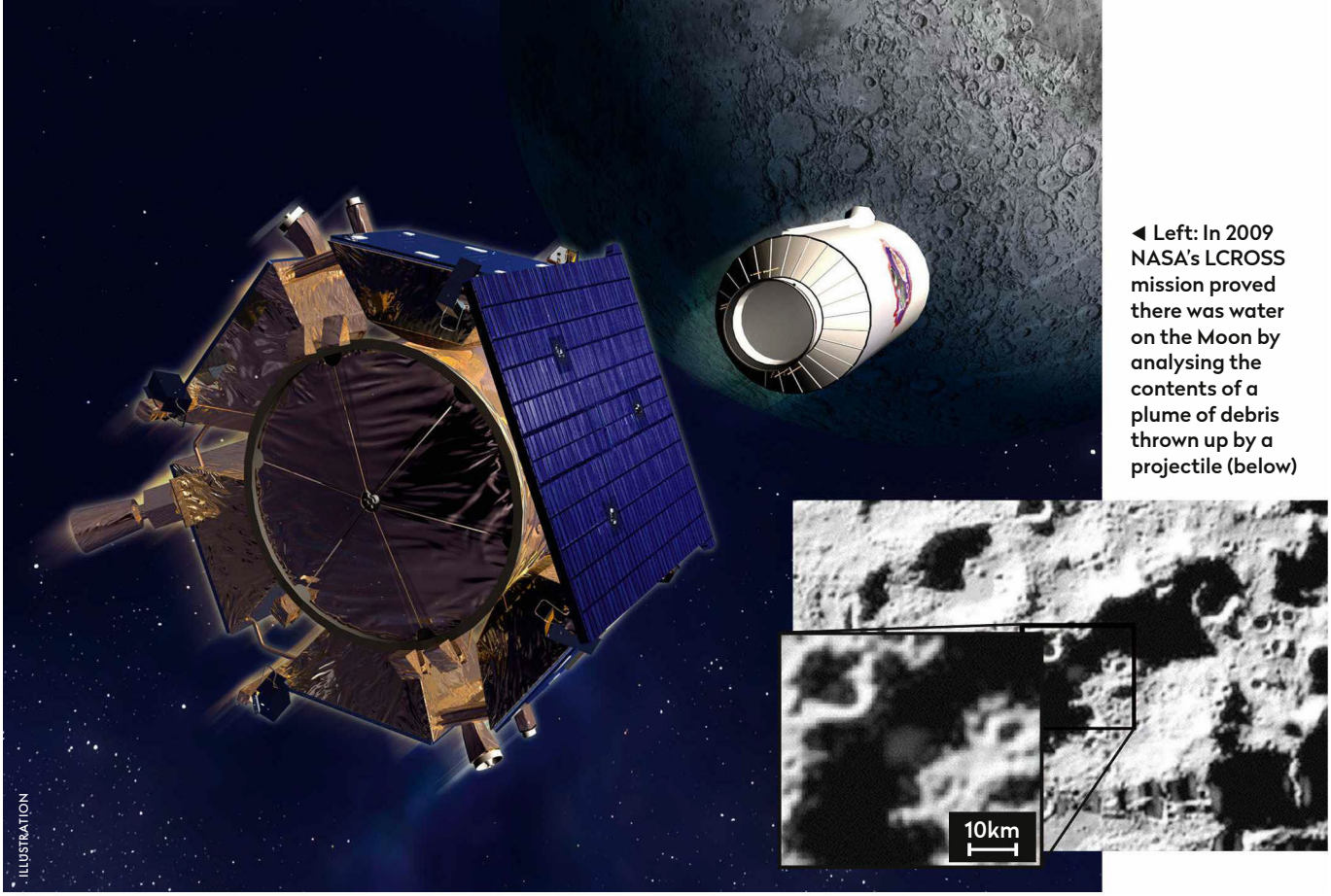
ILLUSTRATION

Penny Wozniakiewicz investigates why astronomers are so concerned with finding water in the Solar System, and why it is vital to our exploration of space

Staring up at the Moon with the naked eye, we can forgive early astronomers for assuming the dark patches spread out over its surface were seas – or 'maria' as they were named, after the Latin word for seas. Informed by centuries of ever-improving observations and over 60 years of space exploration, we now know the maria are not seas but rather vast expanses of volcanic basalt that erupted over the lunar surface several billion years ago.

The Moon is in fact very dry: more so than any desert on Earth. Yet despite that, on 23 August 2023 the Indian Space Research Organisation's Chandrayaan-3 mission successfully deployed its lander and rover near the lunar south pole in search of water.

So why search for water in such a dry location? Although there is no liquid water on the Moon, water is present in the form of ice trapped between grains in the lunar soil and incorporated into minerals and glassy beads produced by impacts. The potential for such hidden water was first suggested by remote observations of the surface, and later confirmed by NASA's LCROSS mission, which in 2009 fired an empty rocket stage into a crater on the lunar surface and identified ice in the plume of material ▶



ILLUSTRATION

◀ **Left: In 2009 NASA's LCROSS mission proved there was water on the Moon by analysing the contents of a plume of debris thrown up by a projectile (below)**

▶ flung up from the crash site. Further observations of the surface by the likes of the NASA and German Aerospace Center's SOFIA telescope have since suggested the south polar region of the Moon in particular may host far more water than we ever imagined. As much as 100–400mg of water (about one raindrop) may be present in each kilo of soil.

While this may seem a small amount, it has prompted several space agencies to propose lunar surface missions and instruments to find and characterise lunar water over the next decade.

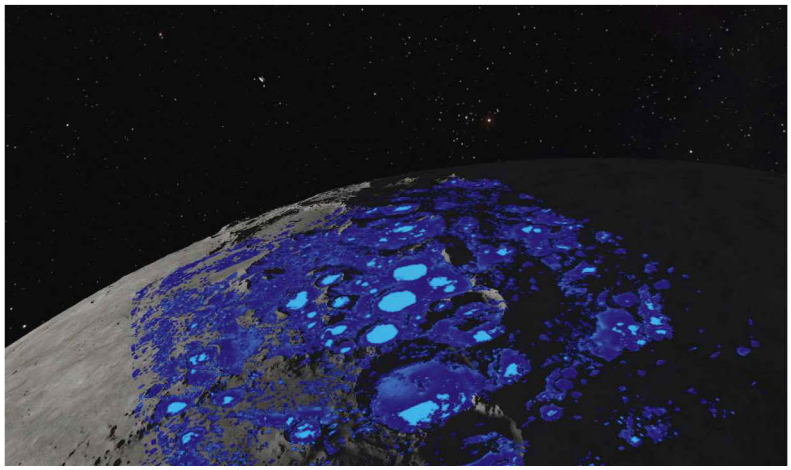
PROSPECTing for water

One such instrument is the European Space Agency's (ESA) PROSPECT payload, destined for the south polar region. This consists of a drill to dig down and obtain samples from the near-surface, together with an onboard laboratory that will subject samples to heat and measure the gases, including any water vapour, that are released.

"Should water really be present in such significant quantities, the potential implications would be enormous, especially for upcoming human exploration programmes," says Dr Dave Heather, PROSPECT project scientist at ESA. "Water is essential for human survival. It can be used for drinking and also be broken down into its constituent components to provide oxygen for breathing."

All life as we know it needs water. We ourselves are made up of 55–60 per cent water and we need a continuous supply to stay alive. Water is also needed for daily hygiene and, if a colony is to be even remotely self-sustaining, for growing crops. Water also has another handy use up its sleeve – if you split it into hydrogen and oxygen, you get the components for rocket fuel.

But space travel is a costly business, and one that gets more expensive and more complex the more you want to take with you and the further you want to go. Minimising mass on board spacecraft is a high priority for space agencies and mission engineers. Since water is vital to any human space mission, it cannot simply be left behind, but perhaps now we can mine it from lunar soils.



▲ **The lunar south pole is thought to be the Moon's most water-rich region**

Dr Mahesh Anand, a professor of planetary science at the Open University, is exploring ways to do this. "Water is considered a key resource for enabling a more affordable and sustainable exploration of the Moon," he says. "The availability, extraction and utilisation of water in situ on the Moon would therefore lower the cost and risks for future missions."

If the Moon harbours water, where else might we find it, and in what form? Today, Earth is the only planetary body in our Solar System with sustained liquid water present on its surface. This is because water exists as a liquid at a range of pressures and temperatures that are found, thankfully for us, on Earth's surface. However, over the last few decades a plethora of telescopes and spacecraft have shown that water is present throughout our Solar System.

NASA X 2, ESA, NASA/JPL-CALTECH/MSSS, NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/TEXAS A&M UNIVERSITY, WALTER MYERS/SCIENCE PHOTO LIBRARY

ILLUSTRATION

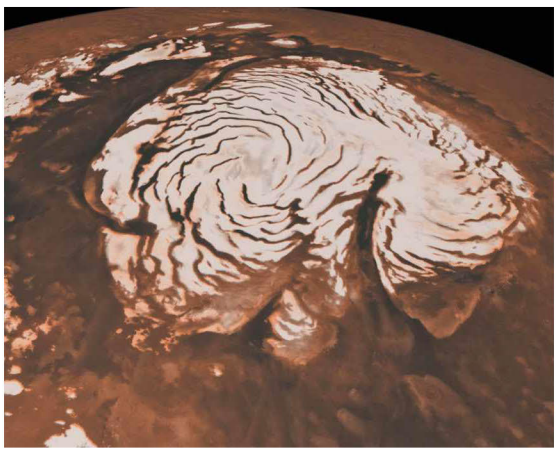
The volume of water on Earth is actually quite small compared to the planet's volume overall. Further out in the Solar System, this is not the case

How Earth became blue

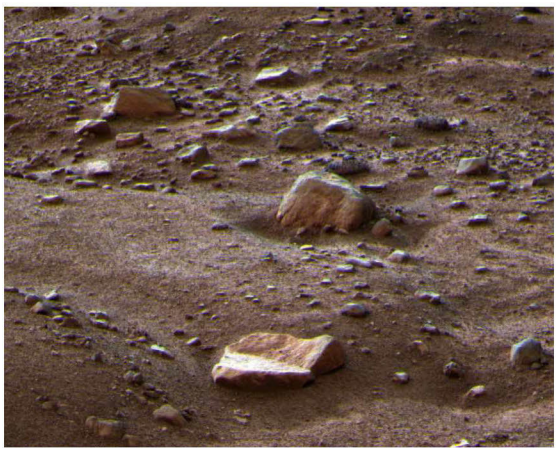
Was Earth always so aqueous? A short history of water on our planet

Today, over 1,000 quintillion litres of water exist on Earth, most of which make up the oceans that cover over 70 per cent of its surface. Our Blue Planet may be blue now, but things may have been quite different when it first formed.

In some formation theories, the early Earth was initially dry, having formed in the inner region of the Solar System inside the so-called 'snow-line', close to the Sun, where temperatures are so high that volatiles like water are in their gaseous form. The snow-line is the distance from a star beyond which temperatures on a planetary body become low enough for water to condense out from gas and form solid icy grains. In this scenario, it is believed that Earth's water was delivered later by impacting comets and asteroids. In contrast, planetary bodies forming beyond the snow-line in the outer Solar System were fed with plenty of icy materials. This is evident when we compare the size of Earth's water reservoir with those estimated for the largest Kuiper Belt objects (such as Pluto and Charon) and the icy satellites of Jupiter, Saturn, Uranus and Neptune.



▶ Water ice is plentiful at Mars's north pole: the area depicted is around 1,000km across



▶ Images from Martian rovers have revealed frost on the ground in the early mornings

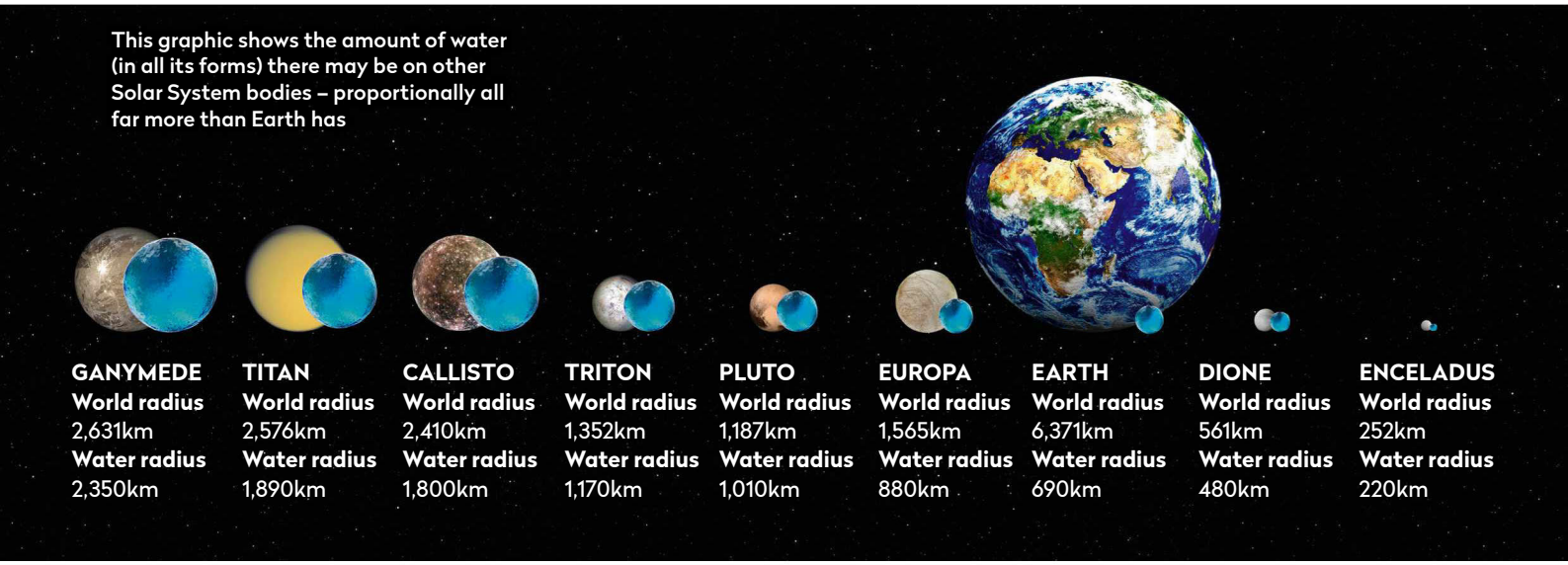
We need only look as far as the other terrestrial planets, Mercury, Venus and Mars to find it. Venus is closer to the Sun than Earth and has an extremely dense, carbon dioxide-rich atmosphere that means its surface is like an oven day and night. You might think such a planet could not possibly host liquid water. Nevertheless, water is present on Venus, albeit only as vapour in its atmosphere.

Mercury sits even closer to the Sun than Venus, but its thin atmosphere means the surface continuously oscillates between hot and cold during the night as the planet rotates. You might expect any water present to have boiled off completely, yet there is evidence that, just like on Earth's Moon, water is present as ice within permanently shadowed regions of craters near Mercury's poles.

Mars and beyond

On Mars, water ice can be found in plain sight in the polar ice caps. Yet there is also evidence of vast quantities of it – perhaps more than five million cubic kilometres – hidden beneath its surface. If all this ice melted, there'd be enough water to create an ocean 35 metres deep over the entire surface of Mars – or fill Loch Ness over 650,000 times!

Water is also present on Mars, in small quantities, as tenuous clouds high in the atmosphere. Near the poles, visiting Mars landers have observed water freezing out of the atmosphere at night, forming a frost on the ground. ▶



▶ Moving beyond Mars we reach the asteroids, which also contain water: potentially hundreds of billions of litres of the stuff. On many asteroids this water has become incorporated into minerals, but on some, like Ceres, water is still present as ice. Indeed, Ceres's low density suggests that as much as 25 per cent of the dwarf planet could be water ice.

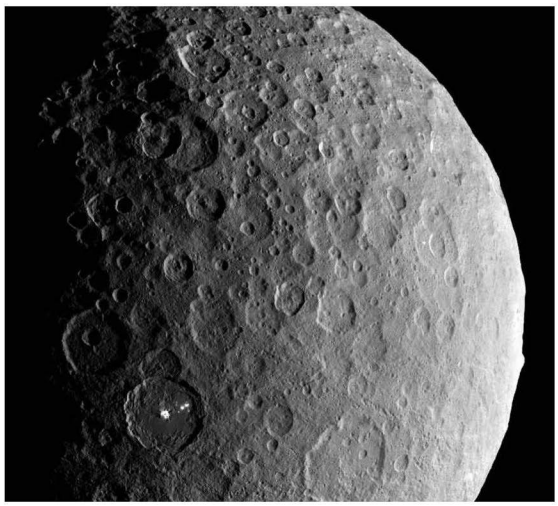
At the giant planets, Saturn and Jupiter both have water vapour in their atmospheres, while Uranus and Neptune are thought to have a water ice mantle lurking beneath theirs. Water ice also dominates the spectacular rings around Saturn, accounting for around 99 per cent of the 15 billion billion kilos of material. That's over half the amount of ice currently in the Antarctic ice sheet, but spread out over a much larger area. Perhaps more excitingly, it seems water is also present as ice on many of the moons of the giant planets, and it may even be liquid on some.

Below the surface

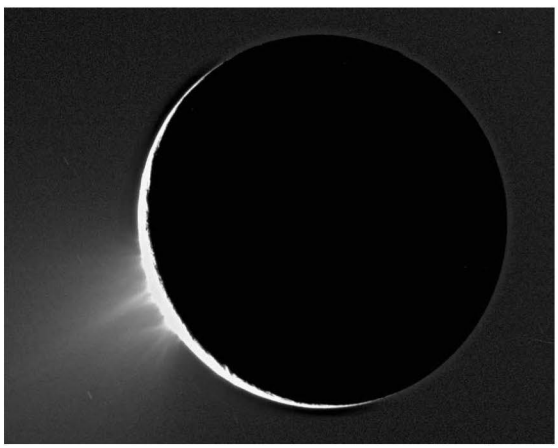
As far as we know, the only surface oceans in our Solar System are found on Earth. However, there is evidence for subsurface oceans on at least the Jovian moons Ganymede, Callisto and Europa, and the Saturnian moons Enceladus, Dione and Titan. Indeed, the total water content (liquid and ice) of these bodies is around 80 times that of Earth.

While heating by the Sun at these distances is minimal, the presence of liquid subsurface oceans on these icy worlds is thought possible due to tidal heating, whereby heat is generated as the moons are squashed and squeezed by the gravitational pull of their parent planet fighting against that of their sibling satellites.

During its visit to the Saturnian system, the Cassini spacecraft beamed back remarkable images showing plumes of water vapour and ice grains shooting out from Enceladus's surface. Using the Cosmic Dust Analyser (CDA) on board, Cassini was able to sample and study these plumes. "We found salt- and carbon-rich water ice grains originating from a large reservoir of liquid water below the icy crust of Enceladus," says Dr Ralf Srama, astronomy professor at University of Stuttgart and lead scientist for the CDA.



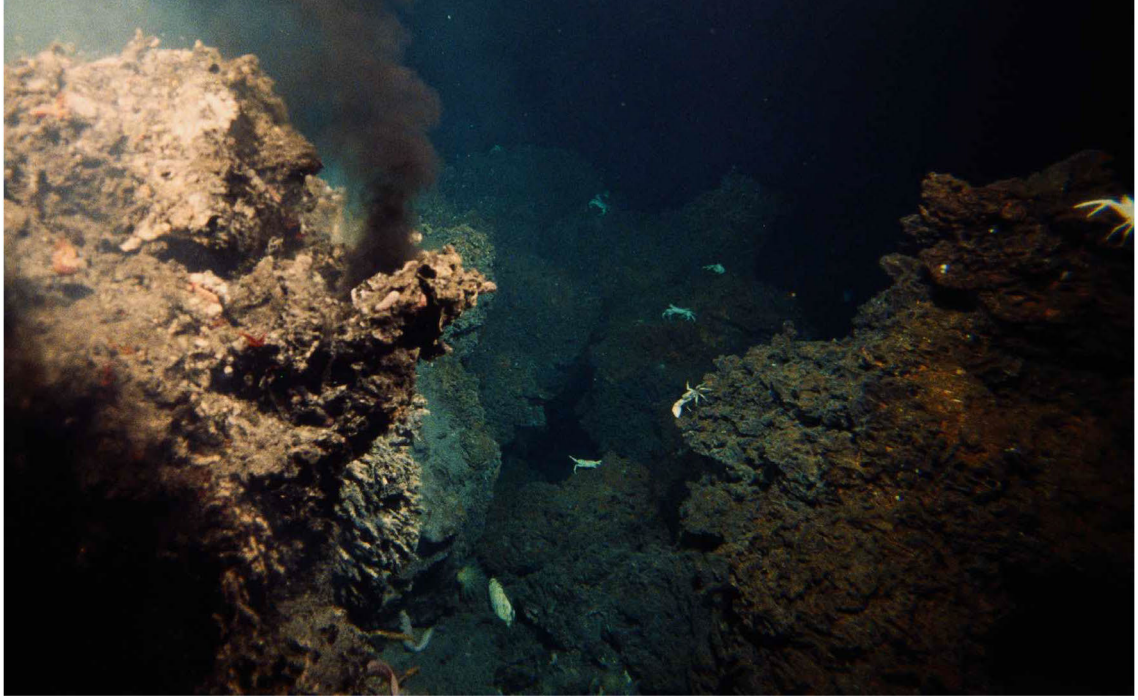
◀ **Located in the asteroid belt, dwarf planet Ceres may consist of up to 25 per cent water ice**



◀ **Massive jets of water erupt from the surface of Saturn's moon Enceladus in this Cassini image captured in 2017**

The existence of subsurface oceans is exciting because of the potential significance to the question of whether suitable conditions for life might be found beyond Earth. Scientists like Dr Frank Postberg, professor of planetary science at the Freie Universität Berlin, have been working with plume data from CDA to study conditions below Enceladus's icy crust. He says, "We found a variety of salts that tell

WATER IN SOLAR SYSTEM ILLUSTRATION: SOURCE - STEVE VANCE/NASA/JPL-CALTECH, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA, NASA/JPL/SPACE SCIENCE INSTITUTE, MARK GARLICK/SCIENCE PHOTO LIBRARY/ALAMY



▶ Hydrothermal vents like those in Earth's oceans could potentially enable life to survive in subsurface oceans on other worlds

Penny Wozniakiewicz is a senior lecturer in space science at the University of Kent

us Enceladus's subsurface ocean is a little less salty than Earth's ocean, and is a 'soda ocean' with lots of dissolved carbonates and carbon dioxide, which also provide more alkaline waters than on Earth."

Promisingly, they also identified organics (which are needed for and can be created by life), phosphorus (which is essential for life as we know it) and minerals that indicate hydrothermal activity – a proposed mechanism for providing materials for chemical reactions and heat in the dark, subsurface world.

Although few spacecraft have ventured beyond Saturn, those that have revealed evidence of water ice on the moons of Uranus and Neptune, and on Kuiper Belt objects such as Pluto, which is thought to be composed of up to 30 per cent water ice. Comets, which we observe from Earth as they traverse the inner Solar System, can originate from the Kuiper Belt or the more distant Oort Cloud and are also laden with water ice. Hundreds of thousands of such icy bodies may occupy the Kuiper Belt, while there may be hundreds of billions or even trillions of them in the Oort Cloud.

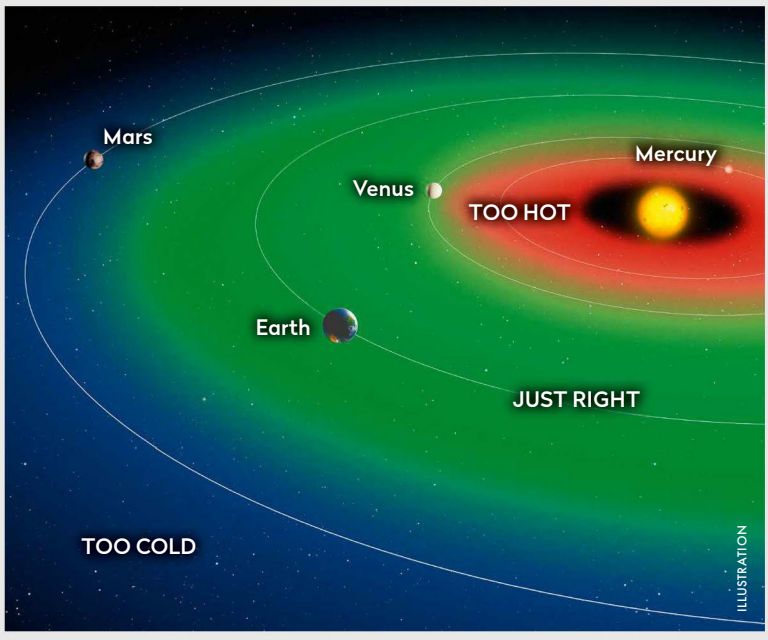
Water in various forms is abundant in our Solar System. Observations of other nascent and established systems suggest that they, too, contain water. If space exploration requires water to be present in the locations we wish to visit, it seems our possible destinations are endless.

Where there's liquid, there's life

Follow the water, says NASA, and you just might find signs of sentience beyond Earth

Liquid water is an essential requirement for life as we know it. It acts as a solvent, breaking down and dissolving substances into a form that can be used by life, also providing a liquid medium in which they can then move, interact with other substances and take part in the key chemical reactions that define life. The presence of liquid water is therefore considered a key requirement for any potentially habitable location beyond Earth, with NASA adopting the mantra 'follow the water' in its search for evidence of past and present life on Mars, and the study of its potential habitability.

Indeed, the presence of water is used to define the 'habitable zones' around stars – these are the range of distances from a star at which an orbiting planet may be heated enough by the star's radiation to have liquid water on its surface. But with the discovery of subsurface oceans way beyond the outer limits of the Sun's habitable zone, our own Solar System has shown us that the situation is not so simple, and that niche or local habitable zones made possible by processes such as tidal heating may also exist – and potentially enable life.



▲ The habitable zone, also known as the Goldilocks zone, is the area around a star where liquid water can exist on the surface of orbiting planets. Outside this region, there can still be water in the form of ice or vapour

Well-chosen eyepieces can bring out the best from your telescope, make astronomy a real pleasure and take your observing from mediocre to mind-blowing

Build your EYEPIECE COLLECTION

Great eyepieces are crucial to any astronomical setup. Here **Tim Jardine** arms you with the info you need to choose the best ones to invest in

Many new telescope packages come with a basic eyepiece or two, good enough to help you get started with the hobby and familiarise yourself with your equipment. Plenty of experienced astronomers will hold fond memories of their first view of Jupiter or Saturn through these starter eyepieces. But it doesn't take long until you start wondering... how much better would the view be through a different lens?

It's fair to say, though, that the choices on offer can be bewildering. Especially given the nomenclature: you might hear of Plössls, orthoscopics, radians and Naglers, or even Kellners and Erfles, and find each costing anywhere between £25 to an eye-watering £1,000 plus – which is perhaps more than the telescope itself!

However, if you can decipher all these terms, you should be able to build a well-chosen selection of four or five eyepieces that will provide high-quality views of everything the night sky has to offer for many years to come. ▶

Tim Jardine is an experienced astronomer and a seasoned telescope tester for *BBC Sky at Night Magazine*

Types of eyepiece

Wide fields of view offer an immersive, but expensive, option

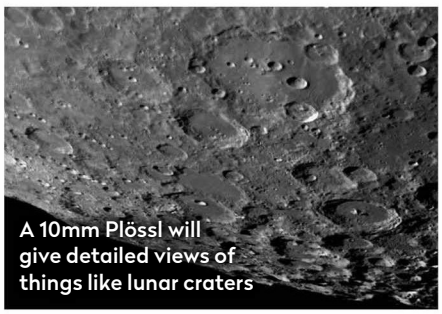
There are a great many types of eyepiece on offer, but essentially, the difference between them is the apparent field of view. This is measured in degrees as seen by the observer. The human eye can see around 180° in the horizontal plane, and so the closer to this an eyepiece gets, the more immersive your viewing experience will be. Generally, the wider the view on offer, the more complicated the eyepiece's design and the higher the price.

At the narrower end of the scale, orthoscopic and Plössl designs offer around 40° and 50° views respectively, and are popular for smaller targets, such as planets, lunar craters and double stars. As a middle-of-the-road option, there are a good variety of lenses available between 62° and 82°, such as those on offer in the Pentax XW and Baader Morpheus ranges, which can provide very comfortable wider views.

The premium end of the market is occupied by the ultra-wide eyepieces from Explore Scientific and Tele Vue, offering absorbing 100–120° views through complicated, heavy lenses. These can really draw you into the scene with breathtaking visuals, but at considerable cost. Wide-view eyepieces are especially useful when observing extended nebulae, large galaxies and open star clusters.

You'll get similar magnification from these two eyepieces, but the right has a larger field of view – and price tag

Another factor you'll need to consider is focal length, sometimes described as the eyepiece's 'power'. This determines the magnification you'll see, which means a 10mm 40° eyepiece will offer the same magnification as a 10mm 100° eyepiece. You should always be able to find the focal length of an eyepiece written on its side, in millimetres. We'll cover how you can work out the magnification later, but as a quick guide: the lower the focal length, the higher the magnification.


A 10mm Plössl will give detailed views of things like lunar craters

While the preferred field of view can be a matter of personal taste, your telescope will have a much bigger say in which focal lengths are suitable. There's no point trying to force huge magnifications from telescopes that can't support them. In theory, the aperture of a telescope, measured in millimetres, can be doubled to give you a maximum magnification. For example, a 100mm-aperture telescope can be taken up to a magnification of 200x, and a 200mm up to 400x.

In practice though, the maximum usable magnification is limited by Earth's turbulent atmosphere. Even on the very best nights of good seeing, 250x is about as high as you'll go for most observing, no matter the telescope size. When building your collection, it's sensible to start with a range of usable magnifications, realistically between 40x and 180x.

▶ Focal length, field of view, magnification and budget are all considerations when building your collection

TIM JARDINE X 6, STEVE MARSH

▲ A 2-inch eyepiece is likely costlier but usually offers extended eye relief and more comfortable observing

▲ In addition to flip-down rubber eye cups for glasses wearers, some eyepieces have an extendable twist-and-lock barrel to personalise the eye relief setting

Quantity or quality?

Finding the right fit for you isn't always just about the price

Experienced observers will likely state that they would rather have one or two good-quality eyepieces than a case full of inferior ones. Often a favourite lens comes to the fore, becoming the go-to tool for most observation. But it does not necessarily follow that the most expensive unit is the preferred one.

Seemingly little things can make all the difference. Better eyepieces will be described as fully multi-coated, referring to the non-reflective coatings applied to the lenses. These coatings improve the contrast of your view by reducing reflections within the eyepiece. Consider too the actual build of the eyepiece. How does it feel in your hands? Does it have a rubberised element on the body to help with grip? As they will be used with cold hands in the pitch black, you'll want an eyepiece that's not too slippery or easy to drop. Do the end caps fit well and stay on? Are the rubber eye-guards soft and comfortable? Are they replaceable?

If your telescope focuser supports the use of 2-inch eyepieces, you will find that they offer a better, more user-friendly view at longer focal lengths. They cost more, but you should find it's soon offset by more enjoyable hours using them.

Another factor that determines the comfort of your viewing experience can be the eye relief a given eyepiece offers. Eye relief describes the distance from the rear of the lens to the point that presents the maximum image circle – basically, how close you have to get your eye to the eyepiece. This can be a quite individual element of observing. Even when figures are quoted for eye relief, it is more practical to actually use an eyepiece to discover whether or not it will be agreeable to observe with for an extended time. When purchasing, it can be prudent to check the returns policy of the retailer.

Glasses wearers in particular will find eye relief an important factor. Short- and long-sighted astronomers can usually adjust for their eyesight with focusing, avoiding the need to wear glasses when observing. However, those with astigmatism will need to wear their glasses, and so may find eyepieces with adjustable-length barrels and longer eye relief are more comfortable. It is also possible to purchase special lenses for Tele Vue eyepieces that adjust for astigmatism and remove the need for glasses. In that case, seeking the advice of a knowledgeable dealer is recommended.

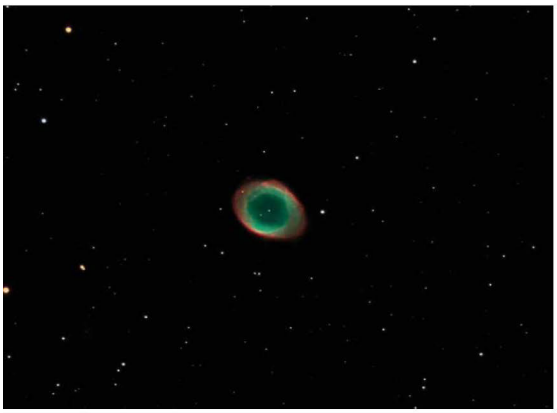
Social media provides a wealth of experienced opinions that can prove helpful when choosing a new eyepiece, or deciding which one to save for. Astronomy forums can be a great source of advice too. Try asking: "My telescope is an XYZ model. If you could choose one eyepiece for it, which would it be?". Hearing real-world recommendations from existing users can be invaluable, especially when they can recommend a budget eyepiece with solid performance or explain the reasons they feel it's worth investing in the high-end examples with the hefty price tags. ▶

The pitfalls of zoom eyepieces

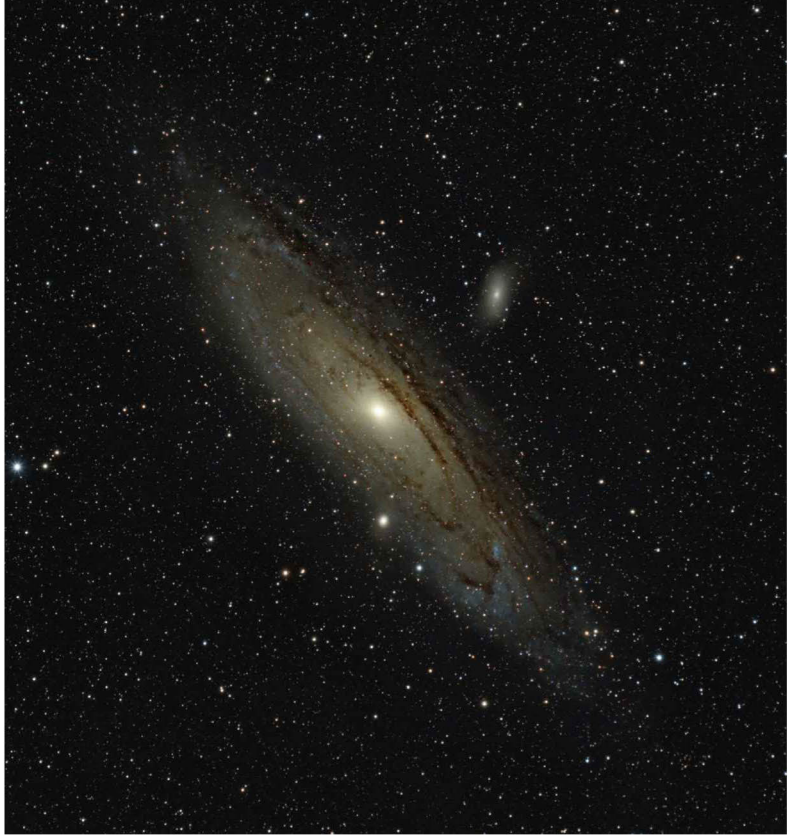
Zoom eyepieces can be twisted to adjust their focal length, offering a range of magnifications from just the one ocular. If they could offer great views, then a zoom eyepiece would be all that was needed. But unfortunately, this isn't the case – the ability to quickly switch between magnifications leads to optical compromises.

A dedicated eyepiece will almost always provide a better view at comparable focal lengths. Zoom oculars can be useful when starting out, to help decide optimal magnifications with your telescope, or perhaps in a shared viewing session if you don't want to keep switching eyepieces. In general, though, once you build your collection, a zoom lens tends to get less and less sky time.

▲ One-lens solutions may cut down faff, but optical quality may be the trade-off



▲ A medium-power 15–25mm eyepiece is suited to deep-sky objects like M13 (top) and M57 (bottom)



▲ For large galaxies like Andromeda or for the full disc of the Moon, long-focal-length eyepieces of 25–35mm will fit the whole scene in the field of view

Choosing which eyepiece to use

Having the right one ensures your observing will turn out alright on the night

Many of us start out by observing the so-called 'lollipops' of our Solar System, bright, easy-to-find objects like the Moon, Saturn and Jupiter. For the deep sky, it's the brighter Messier objects, such as M13, the globular cluster in Hercules, or M57, the enchanting Ring Nebula in Lyra which draw the most attention. While you're attempting to locate these objects, it can be useful to have a wider view. Once pinpointed, you can swap to a higher power with more magnification to see more detail on the lunar surface or planets. Meanwhile, these same eyepieces will make deep-sky objects like M57 stand out more at higher magnification because the background sky appears darker.

So as a minimum, two eyepieces would seem to be essential. When new telescopes come bundled with eyepieces, they typically include two: a wider view lens in the region of 15–25mm focal length and a higher power one in the 5–10mm range for more magnified views.

It's worth remembering that higher magnification doesn't always mean better views. Of course, some targets are quite large, such as the Double Cluster in Perseus, or the enormous Andromeda Galaxy. A more pleasing view of these can be obtained from a wide view, and longer-focal-length lenses, perhaps 25–35mm, can really allow an enjoyable, low-magnification view that encompasses broader objects in full, or allows you to see smaller objects in the context of their surroundings.

▶ Off-the-shelf scopes typically come with a pair of basic starter eyepieces

With such a huge variety of deep-sky options, having a collection which covers the whole range, but is biased towards the type of target you find most appealing, makes a lot of sense. For example, if you appreciate the odd star cluster but spend more time on Jupiter's details, then leaning to shorter-focal-length oculars will allow you to get a close look at the details which the best-view sky conditions allow. Meanwhile, if hunting out distant galaxies is your thing, you will find that a range of lower-magnification wider views provide the sweet spot.

What about a Barlow?

Barlow lenses are combined with an eyepiece to increase magnification by the factor indicated on the barrel. Most common are 2x and 3x Barlows, and with a bit of thought they can effectively double your eyepiece collection. Bear in mind, doubling the magnification means halving the focal length, so with a 2x Barlow lens in place a 30mm eyepiece acts like a 15mm, whereas a 3x Barlow would decrease it to 10mm.

▶ A Barlow can be a great investment, cleverly doubling the magnification of eyepieces you own

FRANZ KLAUSER/CCDGUIDE.COM, GÜNTER KERSCHHUBER/CCDGUIDE.COM, HORST ZIEGLER/CCDGUIDE.COM, TIM JARDINE X 3, WWW.ASTRONOMY.TOOLS

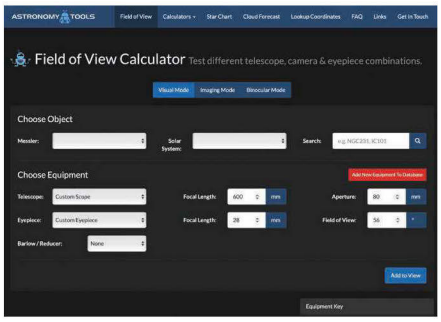
Tools to help pick an eyepiece

Don't worry if you're getting lost in numbers – there are tools to help

To work out the magnification of an eyepiece you just divide the focal length of your telescope by the focal length of your eyepiece. However, there are other useful figures to consider when determining how an eyepiece will perform, such as the field of view on offer.

Another factor is the size of what is known as the exit pupil, which in basic terms is the size of the disc of light emerging from the rear of your eyepieces. To work this out, you'll need the aperture of the objective lens of your telescope, which should be written on it, perhaps labelled as 'D'. Take this number and divide it by the magnification of your eyepiece. For most observing, an exit pupil of 2–7mm is most comfortable as that roughly matches the pupil diameter of your own eye. On nights of good seeing, you may be able to push boundaries even lower for observing smaller details on planets. However, any eyepiece or Barlow combination presenting an exit pupil smaller than 0.5mm should be avoided.

▲ **Find out the aperture of your telescope's objective lens to work out its exit pupil size**



▲ **There's a very useful free field-of-view calculator at www.astronomy.tools**

Thankfully, there are online tools and calculators available which make it very easy to gather all the necessary figures and use them to compare eyepieces against each other. You can find one at www.astronomy.tools, along with other useful, free astronomy tools. Its field of view calculator has a visual representation of what you will see in any given eyepiece and telescope combination, and lists the magnification, effect of a Barlow, exit pupil size and so on.

Completing your set

When it comes to eyepieces, it's about what works best for you

▶ **Whether you colour-coordinate or just mix and match, your collection will be very personal to you**

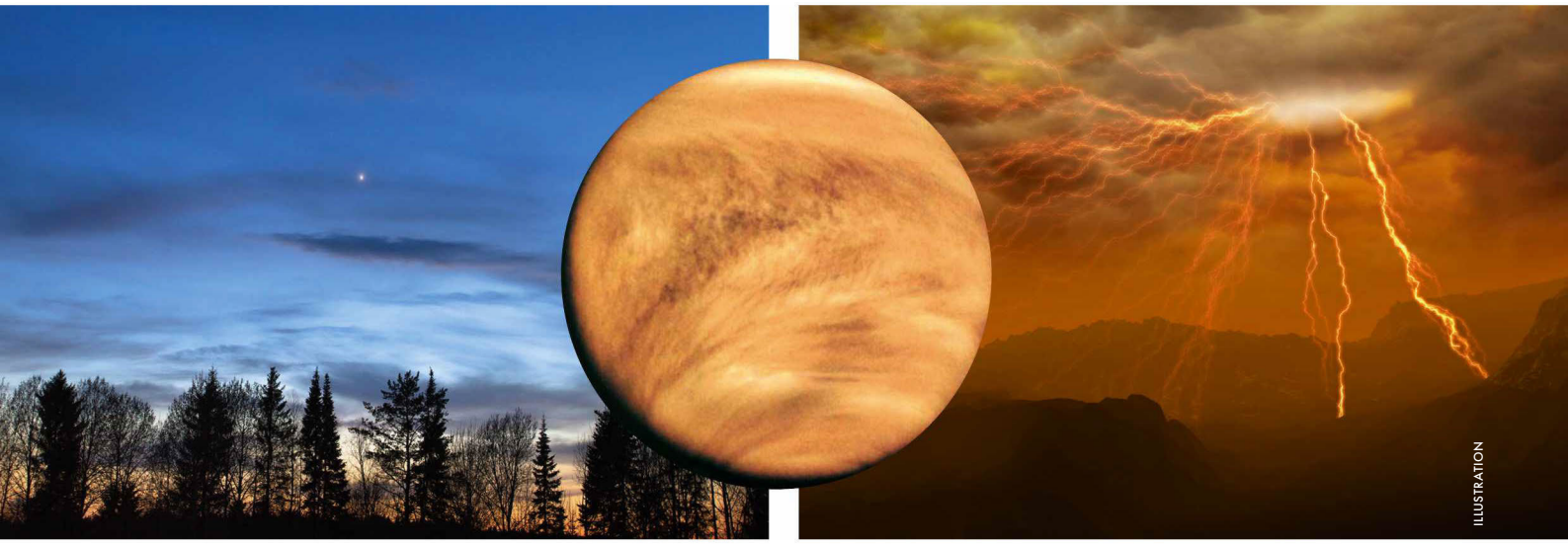
With all these elements taken into consideration – field of view, focal length, eye relief, exit pupil, barrel size, observing type and so on – an eyepiece collection becomes a very personal thing, tuned to your individual requirements, equipment and preferences. However, there is always room for more options, and even though it can only be enjoyed during daylight hours, there is something deeply satisfying about matching sets of eyepieces, and even in matching the colour trim of the eyepiece to the telescope! Whichever direction your tastes dictate, a well thought-out eyepiece assortment will keep you coming back to the telescope, and allow you to relish all the delights of the night sky.

The fundamentals of astronomy for beginners

EXPLAINER

Venus's hostile atmosphere

Katrin Raynor takes a look at a planet where the skies boil and the clouds rain acid



Christiaan Huygens, a Dutch astronomer, first hypothesised the existence of Venus's atmosphere in 1698 when he observed the planet through his telescope. Despite viewing its waxing and waning phases, he could not see any features on its surface and guessed that a thick atmosphere must be obscuring his view. Years later in 1761, Russian Mikhail V Lomonosov detected the refraction of solar rays while observing the transit of Venus across the Sun – and thus discovered the atmosphere of Venus.

In 1962, Venus became the first planet to be visited by spacecraft, when NASA's Mariner 2 flew within 34,854km of the planet. Since then, nearly 40 missions have visited Venus and this month marks the 45th anniversary of NASA's Pioneer Venus mission and the Soviet Venera 11 and 12, all of which collected data about the planet's hostile atmosphere.

Venus is the second planet from the Sun and our nearest planetary neighbour. It has a rocky body similar in nature to Mercury, Earth and Mars. Named after the goddess of love and beauty, and described as Earth's twin, Venus is only 638.4km smaller in diameter than Earth and has a similar mass.

Despite being further from the Sun than Mercury, Venus is the hottest planet in the Solar System. Surface temperatures reach a scorching average of 475°C, a stark contrast to Earth's average of 15°C. It's theorised that four billion years ago, Venus's atmosphere was like Earth's, but today the planet has a dense atmosphere composed of 96 per cent carbon dioxide, 3 per cent nitrogen and the remaining percentage made up of trace elements, including sulphur dioxide. It's believed that early volcanism released carbon dioxide into the atmosphere on both Earth and Venus. But while our planet's plate tectonics helped to recycle this back into the rock, Venus was unable to do so. The carbon dioxide simply built up in the atmosphere.

▲ A beautiful, bright fixture of our skies at sunrise or sunset, Venus has a similar composition to Earth. But our 'twin' is a toxic-cloud-cloaked world ravaged by a runaway greenhouse effect, crushing pressures and lead-meltingly hot temperatures

This locked the planet into a runaway greenhouse effect, where the carbon dioxide in the atmosphere

▲ Venera 9 and 10 sent back the first-ever images of the surface on 22 and 25 October 1975, transmitting for 53 and 65 minutes before contact was lost

PAVELRODIMOVISTOCK/GETTY IMAGES, JULIAN BAUM/SCIENCE PHOTO LIBRARY, NASA X 2, SCIENCE PHOTO LIBRARY/ALAMY STOCK PHOTO, NASA/JPL

ILLUSTRATION

The possibility that phosphine, a signature for life, could be in Venus's atmosphere has been highly contentious

Signs of life over Venus?

Though the atmosphere looks unsurvivable, there could be microbes living in the clouds

Three years ago, Venus hit the headlines when the presence of phosphine gas, a possible life signature, was discovered in the planet's atmosphere. Phosphine, comprising hydrogen and phosphorus, can be found on Earth as the product of natural processes such as volcanic activity, but is also created by anaerobic bacteria living in marshlands and bogs. Could Venus's atmosphere, filled with boiling clouds of sulphuric acid, be home to a similar, yet alien, microbe?

Using the James Clerk Maxwell Telescope (JCMT) in Hawaii in 2017, a team of astronomers led by Professor Jane Greaves of Cardiff University discovered a tantalising hint of the gas in the skies over Venus. Confirmation was later obtained from observations by the Atacama Large Millimeter Array observatory in Chile in 2019.

Controversy soon surrounded the announcement though, with scientists disputing whether the gas had been discovered at all. Groups of scientists posted statements questioning the data, suggesting an absorption line of sulphur dioxide had been mistaken for the presence of phosphine and the data was flawed and analysed incorrectly.

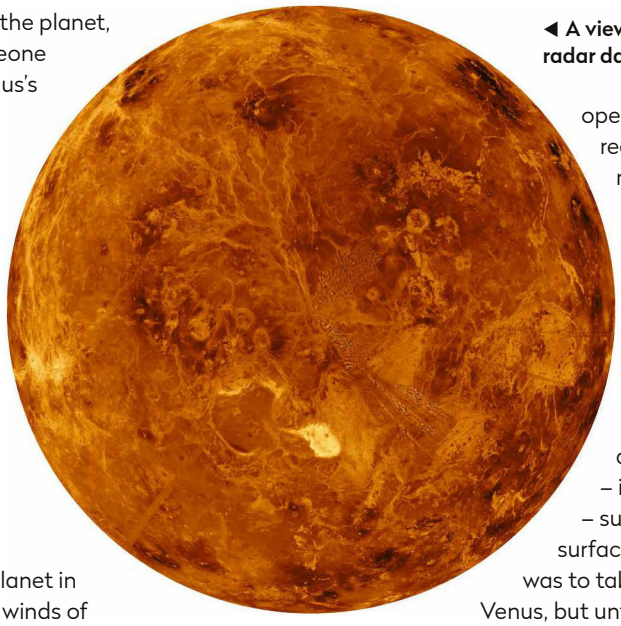
Then, earlier this year, further observations from the JCMT and data from the Stratospheric Observatory for Infrared Astronomy (SOFIA), along with different methods of analysis, again showed signs of phosphine in the planet's upper clouds, backing the initial discovery.

blocks thermal radiation from exiting the planet, resulting in high temperatures. If someone were unlucky enough to stand on Venus's surface, they would experience a pressure over 90 times Earth's – the equivalent of being 3,000 metres below the ocean.

Earth's toxic twin

Venus's atmosphere also makes it the third-brightest object visible with the naked eye. Dense clouds composed of sulphuric acid cover the planet, preventing sunlight penetrating through to the surface. These clouds reflect up to 84 per cent of the incoming rays from the Sun, causing it to outshine most night-sky objects. The clouds race around the planet in days, blown by powerful atmospheric winds of around 300km/h, releasing droplets of sulphuric acid that evaporate before reaching the planet's surface.

The information we have about Venus's atmosphere today is credited to the many missions sent to the planet. After several fly-bys throughout the 1960s and 1970s following Mariner 2, NASA mounted the Pioneer Venus project to enter the planet's atmosphere. In December 1978, Pioneer Venus entered orbit around the planet before deploying the Pioneer Venus Multiprobe (also known as Pioneer Venus 2), containing four smaller probes, into the atmosphere. The orbiter continued to operate until 1992. Crucial data recorded during this mission revealed the absence of a magnetic field, extremely high wind speeds and three cloud layers above the surface.



◀ A view of the northern hemisphere from radar data from NASA's Magellan, 1996

A few weeks later, the French–Soviet Venera 11 and 12 missions arrived. From 1961 to 1983, the Soviets sent 13 spacecraft into the planet's atmosphere, eight of which – including Venera 11 and 12 – survived to transmit from the surface. The main aim of these missions was to take colour photos of the surface of Venus, but unfortunately the camera lens caps failed to open once on the surface. Still, crucial atmospheric data was captured, including evidence of thunder and lightning, and low levels of carbon monoxide at low altitudes.

In recent decades, most spacecraft have only snapped a quick view of Venus as they sped by on their way elsewhere, though a handful – including NASA's Magellan and ESA's Venus Express – stayed for a longer look.

Interest is beginning to grow again, and now three new missions are currently being planned, a potential renaissance for this most hostile of worlds.

Katrin Raynor is an astronomy writer and a fellow of the Royal Astronomical Society

DIY ASTRONOMY

Make a model to show Venus's phases

Show how the planet waxes and wanes as it journeys around the Sun

The Sun and Venus viewed from the 'Earth end' of the model, with Venus seen in its waxing crescent phase

◀ **Your finished model will track Venus's changing appearance during its 584-day orbit**

This month's project is a model that demonstrates the phases of Venus as we see them from Earth. Our model utilises two table tennis balls and some thin plywood. It is operated by a hand crank which rotates the Venus ball around the central Sun ball, while markings on the top indicate significant points around the orbit. The hemisphere of the Venus ball facing the Sun is painted yellow, while the opposite side is black. We added optional LEDs inside both balls to enhance the contrast (although the only source of light is the Sun).

The model very effectively demonstrates some interesting features of the orbit of Venus. Venus (along with Mercury) is an 'inferior' planet, which means it orbits nearer to the Sun than Earth does. They are normally observed close to the Sun in our sky, early in the morning or evening. All planets can be seen in gibbous phases (when more than half the illuminated surface is visible), but only inferior planets can be seen in crescent phases, when less than half the illuminated face is visible.

When Venus nears superior conjunction (passing behind the Sun as viewed from Earth), it appears fully illuminated, but it is too close to the Sun to safely observe. When it nears inferior conjunction (passing between Earth and the Sun), the crescent reduces completely (and we may even be treated to a transit), but the proximity of the Sun again makes observation difficult.

ALL PICTURES: MARK PARRISH

Mark Parrish is a bespoke designer based in West Sussex

As Venus moves to the western side of the Sun, the visibility of the illuminated face increases and the phases are said to be waxing. At the same time, its size appears to reduce as it orbits away from us. As the planet moves to the eastern side of the Sun, the illuminated face reduces and Venus is said to be waning, but the size appears to increase.

When Venus is near its greatest eastern elongation it is visible after sunset. When it is visible before sunrise, it is near its greatest western elongation. The greatest elongation measured east or west for Venus is 45–47° from the Sun. At these times exactly 50 per cent of its surface appears illuminated.

Venus completes its orbit of the Sun in 224.7 Earth days, but Earth is also orbiting (at a slightly slower rate, taking 365.25 days). Thus Venus's orbit as viewed from Earth (its synodic period) takes 583.92 days. From eastern to western elongations is around 141 days, while western to eastern is 443 days.

One turn of the handle represents 584 fascinating days in the life of Venus, providing some educational interest to accompany any observations you make!

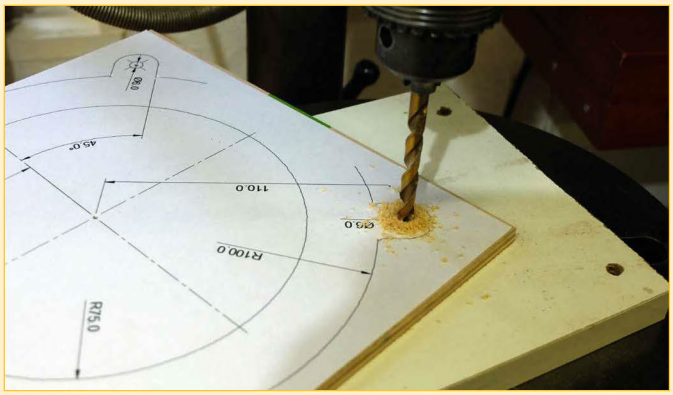
MORE **ONLINE**

Find the plans, template and additional photos to help with your build. See page 5 for details

What you'll need

- Two A4 sheets of good 3mm plywood or similar; offcut of 6mm ply or MDF to make handle bosses
- 500mm of 10mm-diameter aluminium tube (1mm wall thickness)
- Two table tennis balls
- Four M6 x 100 screws, four M6 dome nuts, 10mm bolts and nuts
- Drill, 6mm bit for the leg screws, 10mm bit for the tube
- Coping saw, junior hacksaw, scissors, craft knife, hot-glue gun, soldering iron
- Marking out tools, spray paint, wood stain, varnish, wood glue
- If adding electrics: two LEDs (3V, white, prewired), CR2032 coin cell and holder with switch

Step by step

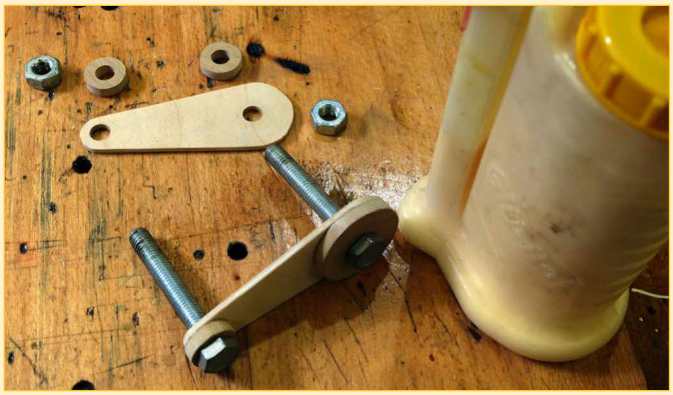


Step 1

Tape the two A4 sheets of plywood together so the finished top and bottom parts match. Print out the template (at 100% scale) and glue it on. Carefully drill the M6 and M10 holes. Use a hacksaw to cut the aluminium tubing to 25mm, 28mm and 37mm.

Step 2

Use a coping saw to cut out the plywood parts. Once done, separate the plywood layers as the top of the frame has a large aperture to cut out. Next, you'll need to use some offcuts of board to make thick discs to support the tubes in the crank.

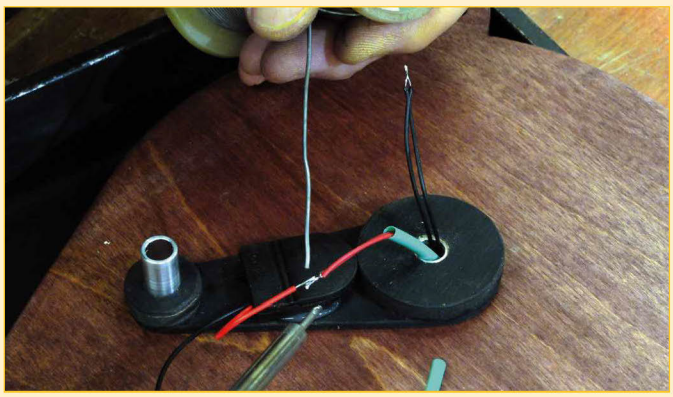


Step 3

Glue together the plywood parts and thick discs for the top section of the crank handle. Repeat for the bottom section. We used two 10mm bolts with washers and nuts to hold the stack of parts together, but be careful not to glue the top to the bottom!

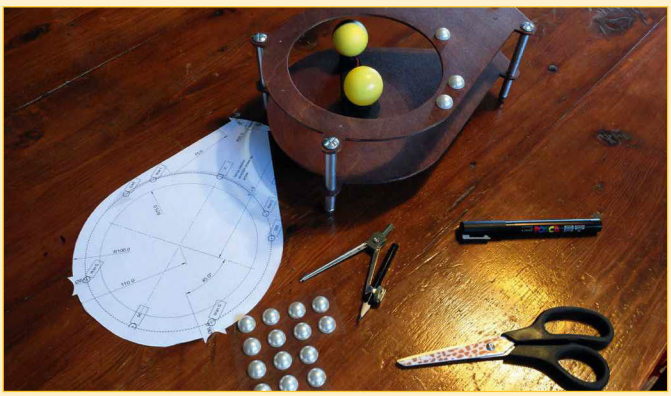
Step 4

Make a small hole in each ball and enlarge with a craft knife to 10mm for the aluminium tube. Mount on temporary sticks and spray both yellow. Mask one off and paint half black. Returning to the plywood parts, use wood stain and varnish to finish them.



Step 5

Push the 28mm tube into the bottom crank for the handle and the 25mm in the top for Venus. The 37mm tube for the Sun goes right through the base to hold both crank pieces together. If using them, feed the LED and cell wires through the holes and solder.



Step 6

Use some hot glue to hold the LEDs in position. Attach the switch and glue on the balls. Make sure the bright side of Venus faces the Sun! Assemble the frame using the long screws and tubes. Use the template to set out the orbit markings.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY

CAPTURE

Photographing the Geminids

Tips for capturing a shooting star during the Geminids peak on 10–16 December

The Geminid meteor shower reaches its peak in the middle of December and this year there's no Moon to spoil the show. If the skies remain clear, this is a fantastic opportunity to capture a meteor on camera.

Viewing or photographing a meteor is a statistical game and anything you do to tip the odds in your favour will greatly boost your chances of catching a trail with your camera. Thankfully, the steps you can take are all fairly simple to implement.

Meteors occur throughout the year, but at certain times the expected number increases. Such periods occur when Earth passes through a comet's orbital debris stream, an occurrence that creates a meteor shower. These streams tend to be wide, creating enhanced activity over a period as short as several days or as long as several weeks. It's in the centre of the passage that activity rises to a crescendo: the peak of the shower's activity.

Set your camera up when there is no shower active and your chances of capturing a meteor are not zero, but they aren't too high either. Do the same thing when shower activity has begun and your chances are much better. Set up on the night of maximum activity and your odds will peak. Not all showers are the same, however. Although the peak of a mid- to low-rate shower does improve your odds, the amount of improvement won't be as much as if you're photographing during the peak of a high-rate shower.

Fortunately, the Geminids is one of the highest-rate showers of the year, with a Zenithal Hourly Rate (ZHR) of 120 meteors per hour. Impressive though this sounds, the actual number of meteors you can expect to see will be lower than this, the ZHR being the predicted rate under perfect skies with the radiant – the point in the sky from which the shower meteors appear to come – directly overhead.

▲ Capturing a meteor trail with a camera requires a large degree of luck as well as skill

Another plus for the Geminids is that the peak is broad, activity remaining high for the nights before and after the predicted peak date of 14 December. This means a session on 13/14, 14/15 and 15/16 December will give you an elevated chance of catching something.

Meteor visibility is improved by the darkness of your sky. If you're in a light-polluted location, picking somewhere darker will help, although this may not always be practical. The absence of the Moon this year will definitely help, though, and is a big natural boost to those all-important odds. The absence of its bright glow is the reason why this year's shower is described as favourable. Next year, the balance will shift so that the Geminids will be unfavourable.

The weather is another important factor. Haze, thin cloud or just clouds will all affect the odds of capture. A perfectly clear sky is best of course, but photography can still be done under less perfect conditions, the chances of capturing a trail simply reduced as a consequence.

In our step-by-step guide opposite we look at some of the setup considerations you can apply to meteor photography, with an emphasis on how to keep your odds of success as high as possible.

Pete Lawrence is an expert astro-imager and a presenter on *The Sky at Night*

Equipment: DSLR or equivalent on a fixed tripod, shutter release cable, a fast mid- or wide-angle lens (12–20mm)

✉ Send your images to:
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

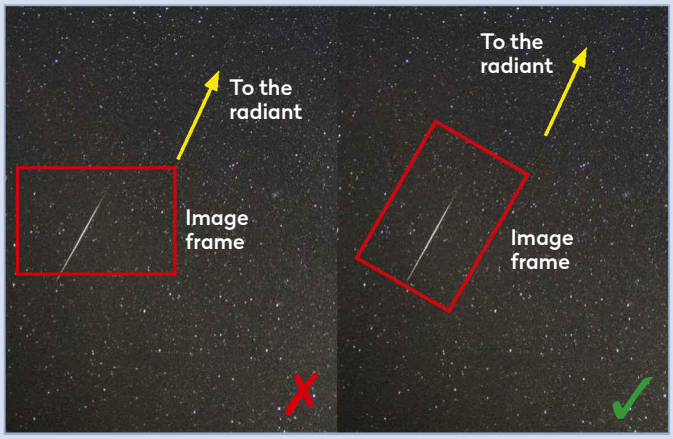
Step by step

STEP 1

A fish-eye lens will give you the best chance of capturing a trail, but the trail will appear small. A compromise may be choosing a mid- to wide-angle lens. A fast lens is preferred, something with a lower minimum f/number than 3.5 being ideal. A focal length of 12–20mm should give you decent coverage and reasonable trails.

STEP 2

There's no need to drive your camera, a fixed tripod being just as good as a tracking platform. Aim the frame centre to point 60° up in any direction. Despite conventional advice, it's pleasing to have the radiant in frame because then you see trails pointing back to it. Trails are shortest near the radiant and longest 90° from it.



STEP 3

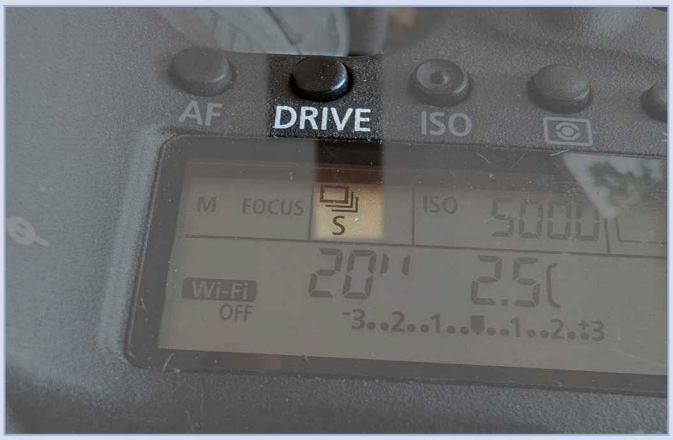
Orientate your camera so the long axis of the frame points to the radiant (see page 46 for the radiant position). This means that any long trails have a better chance of staying in frame. If you can, check the orientation several times throughout the night, realigning the camera to maintain this framing.

STEP 4

Improve your chances of capturing a meteor by choosing a location where there are no foreground objects in the way. In fact, try to have nothing in view except sky. It may seem like a great idea to have a picturesque tree silhouetted in the shot, but this will simply act as an all-too-effective meteor shield. If you're tracking, ensure the image frame remains clear at all times.

STEP 5

Dew build-up is a common issue from moisture-heavy sites when the temperature dips. A dewed-up lens will greatly reduce your chances of capturing a meteor. A 12V hairdryer can be used to gently warm the lens at frequent intervals, say every 30 minutes. Alternatively, a dew heater and wrap-around band is a great solution that will operate unattended.



STEP 6

Open the lens fully. For older cameras, choose one of the highest ISOs available (1600–3200) or a mid-range value on newer models (5000–10,000). Use continuous shutter operation: lock your shutter release cable so the camera takes repeat exposures. Start at 30 seconds, but reduce if the result is too bright or over-saturated.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

Use freeware to create star trail images

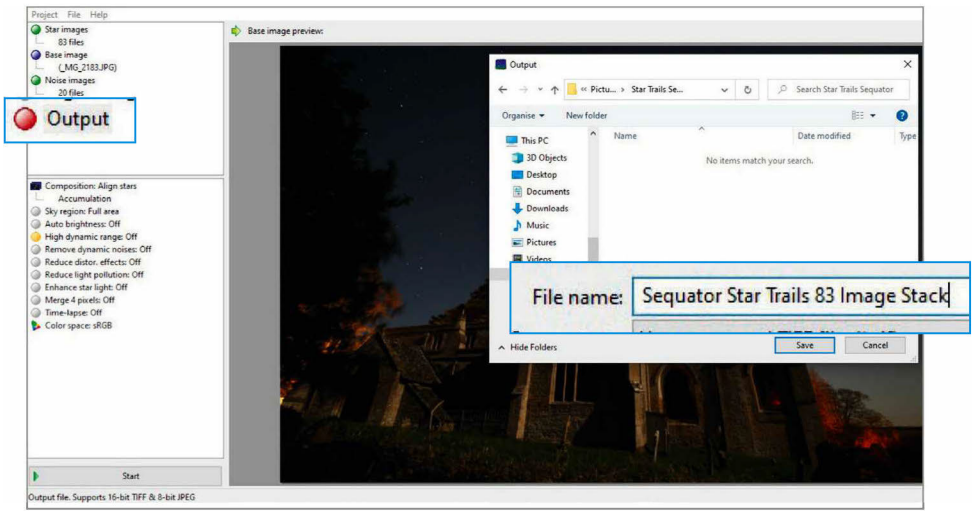
How to turn your frames into beautiful star trail photos in a few clicks

▲ One of Mary's original frames, showing a church prominent in the foreground and a clear night sky behind. Right: her final star trails image after using free and easy-to-use software to stack, align and denoise her 83 exposures of 30 seconds, all taken on a static tripod

Star trails images are a very rewarding type of nightscape photography. Capturing the movement of the stars as Earth rotates on its axis is beautiful in itself, but when it incorporates a nice foreground it really elevates the shot. The great thing about star trail photographs is that they're very easy to produce and can be done with very basic camera equipment.

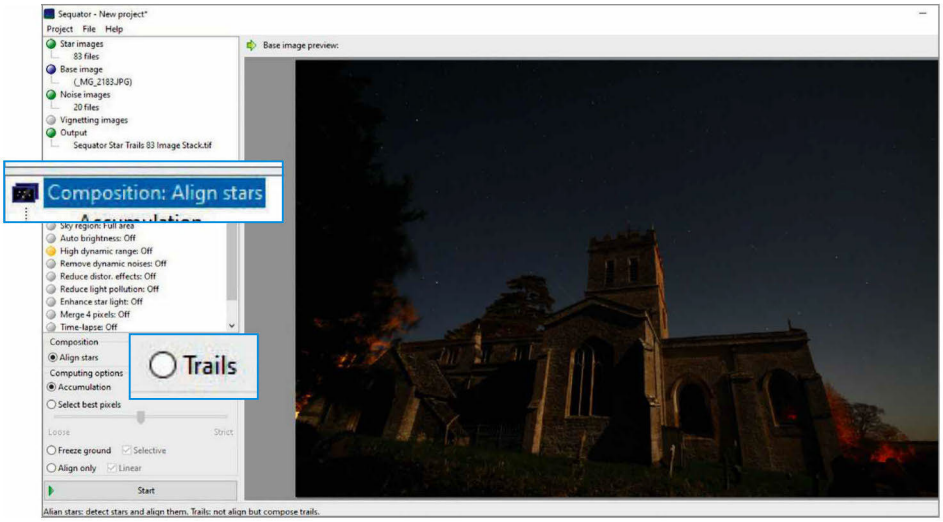
In addition to shooting images with the intention of creating star trails, you can also create them from photographs taken during other imaging sessions. For example, if you've been photographing a meteor shower, aurora display or even a noctilucent cloud display, as long as your camera was on a static tripod and has not been nudged, you can take the images and create a star trail photograph with them. This means that even if you don't capture many meteors or your aurora alert resulted in a no-show, you'll still get a lovely image from the data.

There are several free pieces of software available that will create star trails, but in this example we are using



▲ Screenshot 1: Open the freeware Sequator, load your image files and calibration frames. Double-click on 'Output' and choose where you'd like to save your final image

ALL PICTURES: MARY MCINTYRE



▲ **Screenshot 2: Choose your composition method. Under the 'Composition' tab simply select 'Trails' (not 'Align stars', which will line up your stars but blur your foreground)**

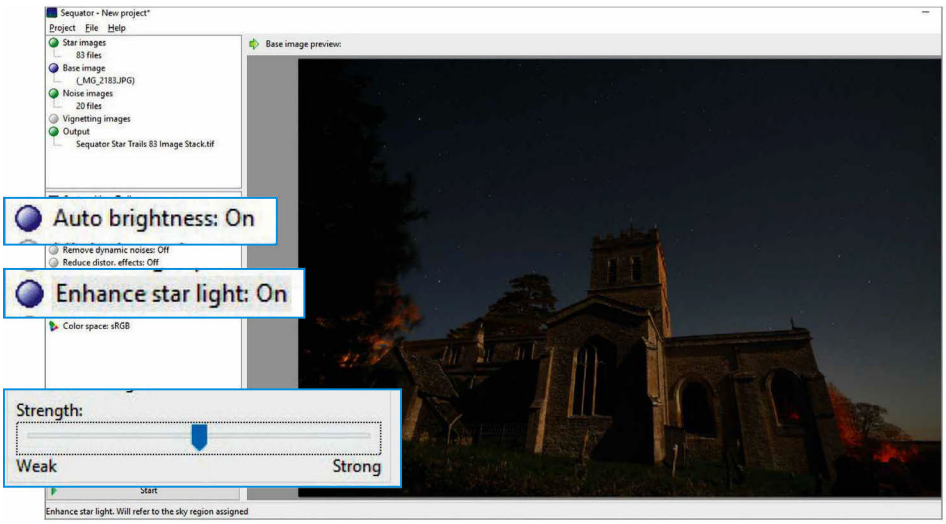
Sequator (**sites.google.com/view/sequator**). The software is free, easy to use, it stacks very quickly and it also has several useful features that can be applied to the output image during the stacking process, reducing the need for further image processing.

A few simple steps

My images were taken using a 10-year-old Canon 1100D DSLR camera fitted with a Canon 10–18mm wide-angle lens, but you could use an 18–55mm or fixed 50mm lens instead. I took 83 exposures of 30 seconds at ISO 800 and f/4.5. The photos were taken during a full Moon and from a position where moonlight nicely illuminated a church. This is the beauty of star trails photography: as long as you're not pointing directly at the Moon, you can still create gorgeous images in a moonlit sky.

To help reduce signal noise from the camera and other artefacts in my image, dark calibration frames were shot at the end of the imaging session. These were captured by simply putting the lens cap on the camera, covering the viewfinder and then taking 20 images with the same settings.

To make your star trail image, start by opening Sequator. Select all of your image files and drag and drop them into the program. When the image category box pops up, select 'Star images'. If you have taken dark calibration frames, then once you've finished importing your star images, select all of your dark frames and drag and drop them into Sequator too, this time selecting 'Noise images' from the image category box so that they don't get accidentally added to the star image frames.



▲ **Screenshot 3: Still under the 'Composition' tab, adjust the overall brightness with the 'Auto brightness' option and use the slider under 'Enhance star light' to boost the stars**

3 QUICK TIPS

1. In Sequator, light frames are called 'Star images' and dark frames are called 'Noise images'.

2. Choose the folder and a file name for your stacked image before you stack the photos.

3. Select 'Trails' in the composition tab to ensure you get a star trails image rather than a photo with all the stars aligned.

In the top-left box you will now see that your images and dark files have been loaded into those tabs. Underneath them double-click the 'Output' tab, then choose the folder you want to save the stacked image into. Click the 'Filename' box and type in a suitable file name.

In the next box down on the left side, double-click the 'Composition' tab. From the box that pops up at the bottom, select 'Trails' – otherwise the software will align the stars, which will blur the foreground. Below this, double-click the 'Auto brightness' tab. This can help to lift areas of your image that are a bit darker; in this case, it brightened the foreground light on the church. Double-click the 'Enhance star light' tab. In the box that pops up at the bottom set the 'Strength' slider to half-way. This will increase the brightness of the stars in your image, which is a very useful feature if your images were taken under a lot of moonlight. Applying too much can look unnatural; less is more.

Finally, click the 'Start' button at the bottom and the final stacked image will be created. It took less than 30 seconds for the stacked image to be produced and the result was good enough without any additional processing. However, just to make the final image even more polished, Fast Stone Image Viewer (**faststone.org**), a free image-processing program, was used to slightly crop the image and make the church tower more central to the composition, and the clone tool was used to remove aircraft trails and any hot, cold or dead pixels that were visible.

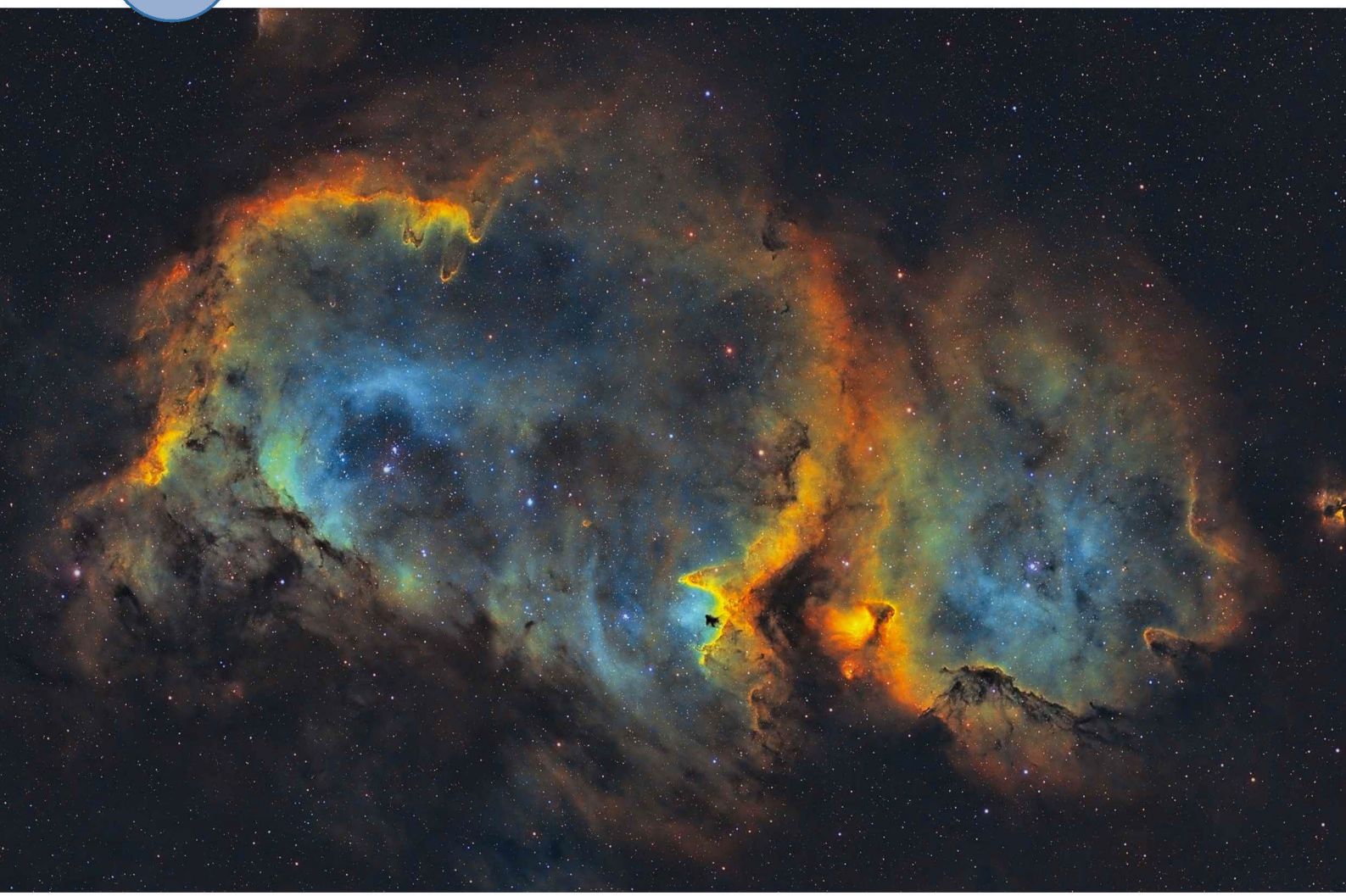
Mary McIntyre is an outreach astronomer and teacher of astrophotography

Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

PHOTO OF THE MONTH



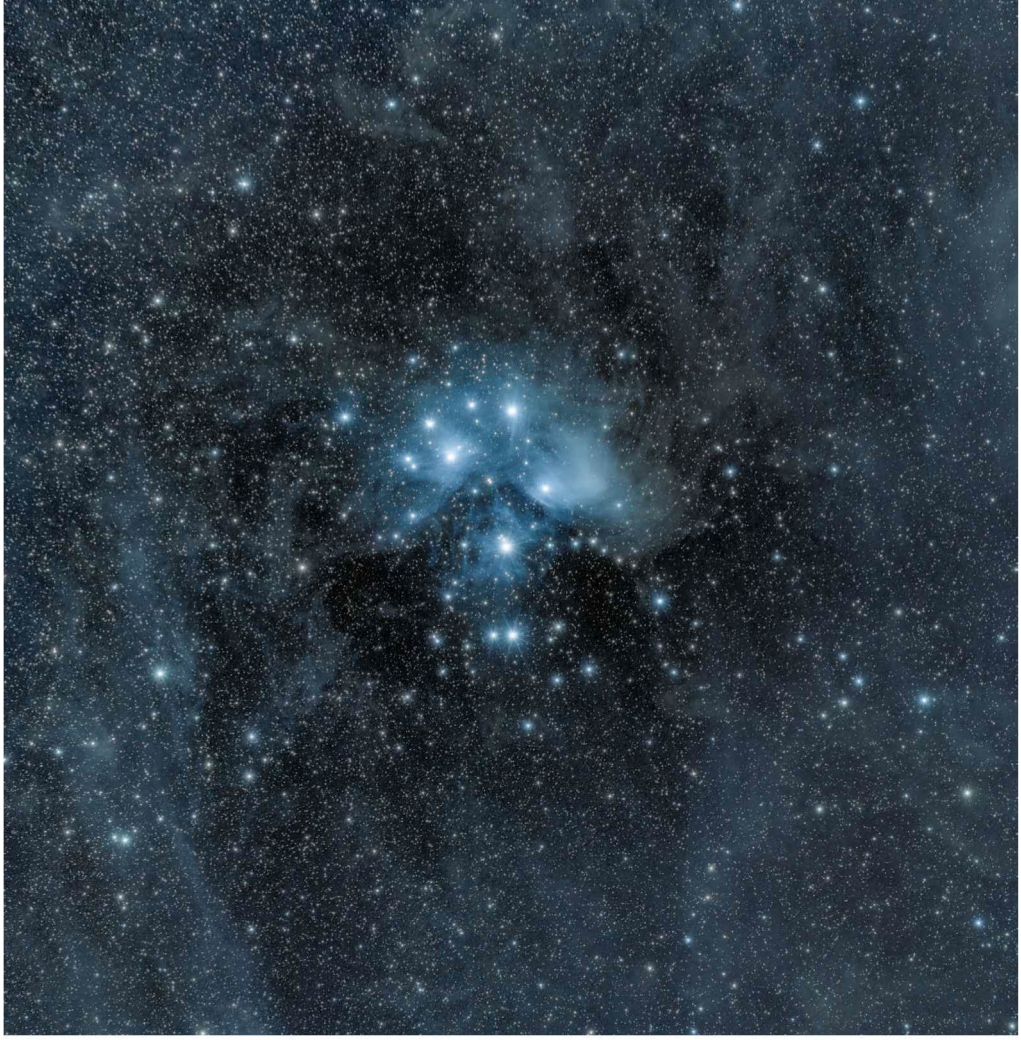
△ The Soul Nebula

Giuseppe De Pace, Turin, Italy, July–August 2023

Giuseppe says: "I chose IC 1848, the Soul Nebula, as my target due to its intricate detail and stunning colour palette. The data capture for this image was challenging as I had to battle against light pollution and bad weather, but the processing went smoothly and I'm pleased with the end result."

Equipment: QHYCCD QHY268M Pro camera, Askar FRA600 f/5.6 astrograph, Sky-Watcher AZ-EQ6 GT mount
Exposure: SII 76x 300", Ha 62x 300", OIII 81x 300", R 30x 120", G 30x 120", B 39x 120"
Software: PixInsight, Photoshop

Giuseppe's top tips: "My advice for astro imagers is to invest in a good-quality telescope or lens with a wide aperture to gather more light effectively. Employ narrowband filters to isolate specific wavelengths of light emitted by the nebula, reducing the impact of light pollution. Longer exposures are often better, but be careful not to over-expose and blow out details. Stack multiple shorter exposures if needed."



◁ The Pleiades

Anthony Bucci, Northern Vancouver Island, Canada, 20 September 2023

Anthony says: "I first tried taking a shot of the Pleiades using just my Nikon camera, but wasn't happy with the results compared to images I was seeing by others. Six months of research and buying deep-sky gear later, this is my latest attempt!"

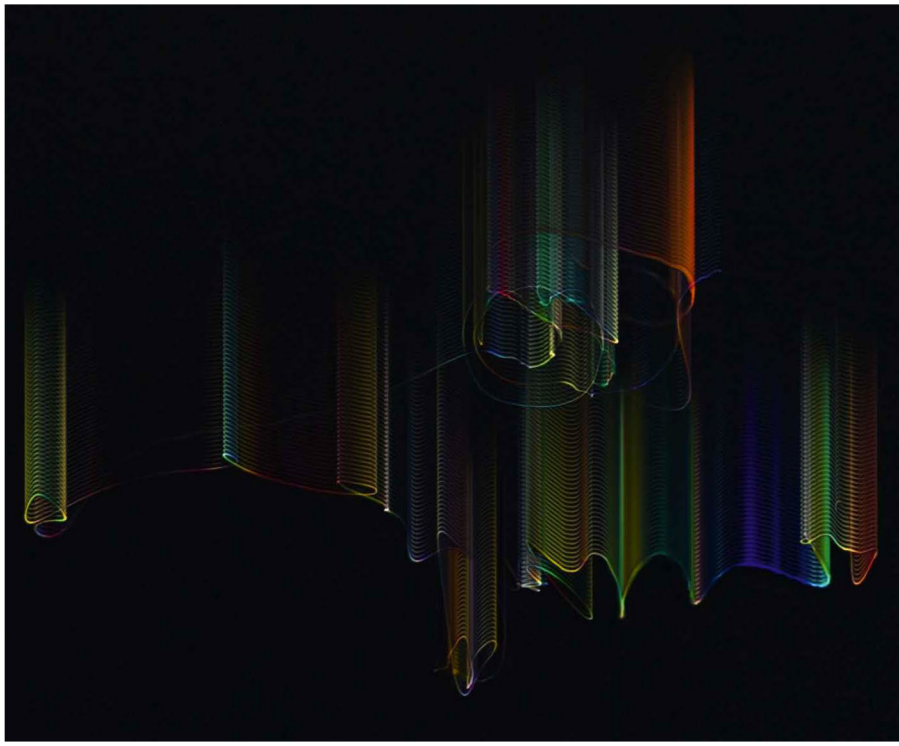
Equipment: ZWO ASI533MC Pro camera, Rokinon 135mm lens, Sky-Watcher EQM-35 Pro mount
Exposure: 138x 120"
Software: Astro Pixel Processor, Photoshop, Lightroom

▽ Partial solar eclipse

John Chumack, Dayton, Ohio, USA, 14 October 2023

John says: "I didn't travel to the centre-line for this annular eclipse, but that didn't mean I wasn't going to try to get the partial from home. There was heavy cloud cover, but I managed to get 11 good SER captures [an image sequence file format] varying from three seconds to one minute."

Equipment: QHYCCD QHY5L-II-M camera, Lunt 60mm Universal Telescope with LS60FHa solar filter, Paramount MyT robotic mount
Exposure: Best 83 of 236 SER frames
Software: RegiStax, AutoStakkert!, AstroSurface

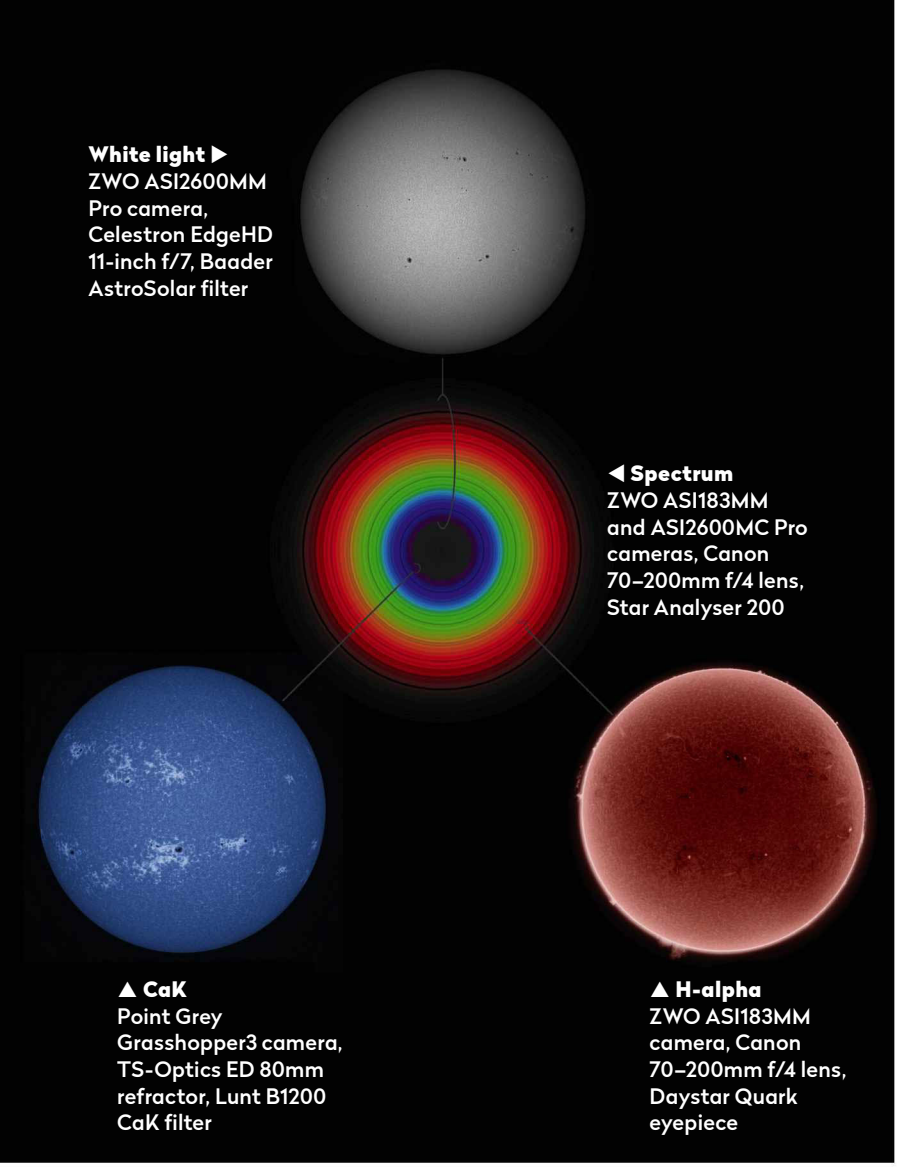


△ Arcturus star trail

Shreya Roy, Kolkata, India, 19 September 2023

Shreya says: "While imaging the Moon I noticed bright star Arcturus and decided to capture its colours by moving my camera on the tripod during a long exposure. I took two pictures this way, then blended and added a motion effect."

Equipment: Nikon D5600 camera, 70–300mm lens, DigiTek tripod
Exposure: ISO 300 f/6.3, 2x 5" **Software:** Photoshop, Lightroom, Snapseed



White light ▶
ZWO ASI2600MM Pro camera, Celestron EdgeHD 11-inch f/7, Baader AstroSolar filter

◀ Spectrum
ZWO ASI183MM and ASI2600MC Pro cameras, Canon 70–200mm f/4 lens, Star Analyser 200

▲ CaK
Point Grey Grasshopper3 camera, TS-Optics ED 80mm refractor, Lunt B1200 CaK filter

▲ H-alpha
ZWO ASI183MM camera, Canon 70–200mm f/4 lens, Daystar Quark eyepiece

◁ The Sun at different wavelengths

Alessandro Ravagnin, Romano d'Ezzelino, Italy, 19 June, 24 June and 29 September 2023

Alessandro says: "To obtain the linear solar spectrum (centre), I captured the sunlight reflected by a needle using a CMOS camera and zoom lens, plus a Star Analyser 200 to break it down. The final image also shows the Sun in white light, hydrogen-alpha and calcium-K – the latter captured by my friend Salvo Lauricella."

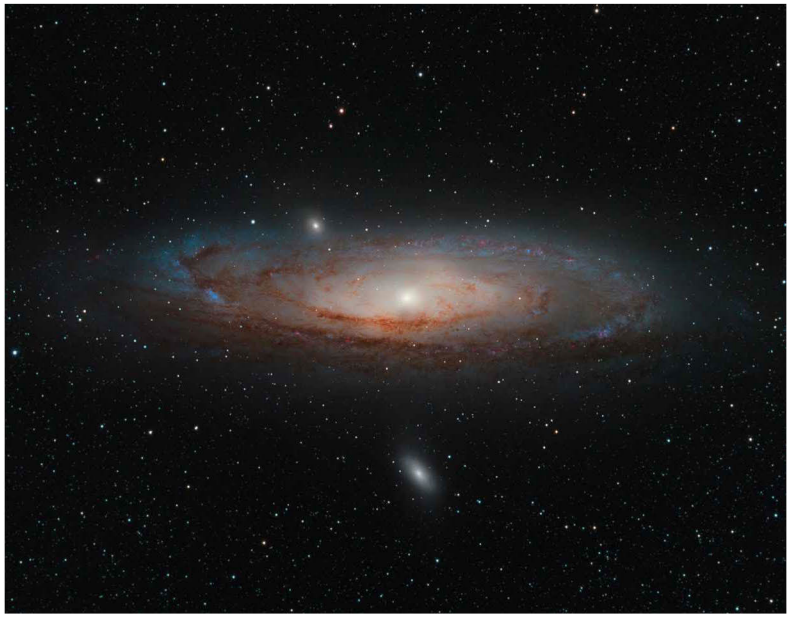
Equipment: As shown
Exposure: spectrum 100x 50ms; white light 100x 10ms; CaK 200x 15ms; Ha 500x 8ms
Software: AutoStakkert!, GIMP, ImPPG, Photoshop

▽ The Andromeda Galaxy

Andrei Pleskatsevich, Minsk, Belarus, 20 September 2023

Andrei says: "To photograph galaxies you need dark skies. In September, while it's still warm but dark, you can shoot all night long. I managed to fit the whole galaxy into the frame, so I'm happy with the result."

Equipment: ToupTek ATR3C571 camera, SharpStar 76EDPH refractor, iOptron GEM28 mount
Exposure: 50x 300"
Software: DeepSkyStacker, Photoshop



◁ Comet Nishimura

Timothy Straub, Prosser, Washington, USA, 5 September 2023

Timothy says: "Several factors were working against me here. First, the comet rose at 03:46 PDT and morning twilight started in earnest at 05:00. I was also dealing with light pollution, high clouds and the Moon close by. But I was pleasantly surprised by the results."

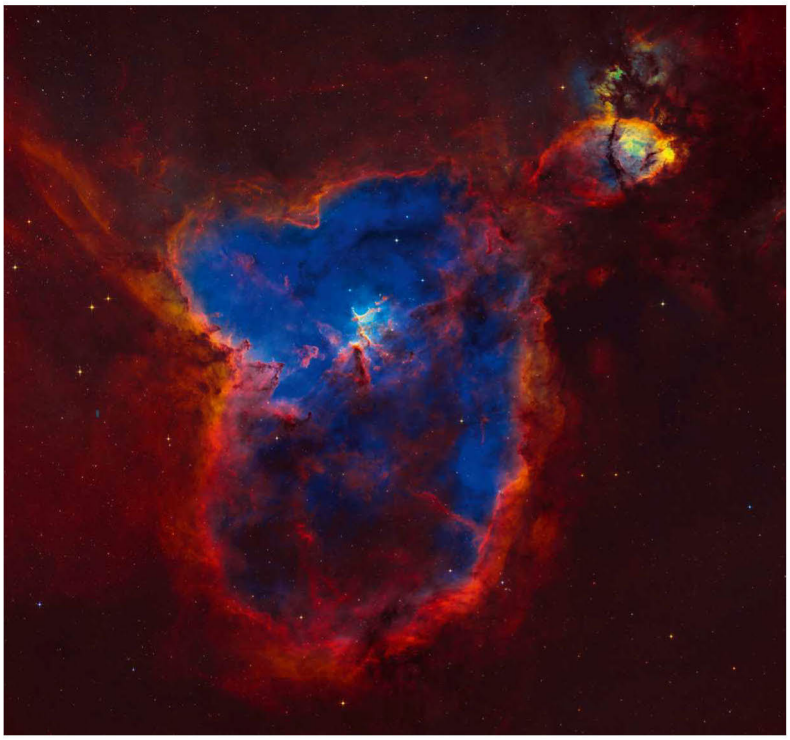
Equipment: ZWO ASI2600MC Pro camera, Celestron C6 Schmidt-Cassegrain, ZWO AM5 mount **Exposure:** 30", 60" **Software:** Photoshop

Star clusters in Cassiopeia ▷

Massimo Di Fusco, Ferra, Italy, 7 September 2023

Massimo says: "I've wanted to capture this for a long time. It shows five star clusters in Cassiopeia: NGC 654, NGC 663, NGC 659, Collinder 15 and M103."

Equipment: Player One Poseidon-C Pro (IMX571) camera, Sky-Watcher Evostar 80ED refractor, Sky-Watcher EQ6-R Pro mount
Exposure: 90x 60"
Software: Astro Pixel Processor, DeepSkyStacker, PixInsight



△ The Heart Nebula

Anirudh Shastry, Sammamish, Washington, USA, 13–14 September 2023

Anirudh says: "The Heart Nebula is one of my favourite targets because of its unique shape and because it has such rich narrowband emissions. I wanted to capture the faint H-alpha emissions in the vicinity of the nebula."

Equipment: QHYCCD QHY600M CMOS camera, Celestron EdgeHD 1100 Schmidt-Cassegrain, Celestron CGX-L mount **Exposure:** Ha 5h, OIII 4h, SII 3.5h **Software:** Astro Pixel Processor, PixInsight, Photoshop

▽ First quarter Moon

Hazen Tobar, Akron, Ohio, USA, 25 July 2023

Hazen says: "This is my favourite lunar picture I've taken to date. I love how the shadows accentuate the area of Mare Imbrium and Montes Apenninus."

Equipment: Canon EOS 6D camera, Celestron NexStar 127SLT Maksutov-Cassegrain
Exposure: 220x 1/100s
Software: PIPP, AutoStakkert!, Lightroom

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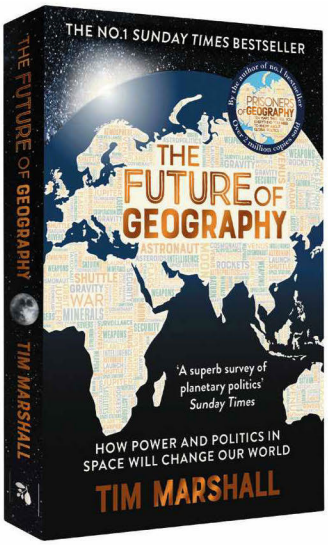

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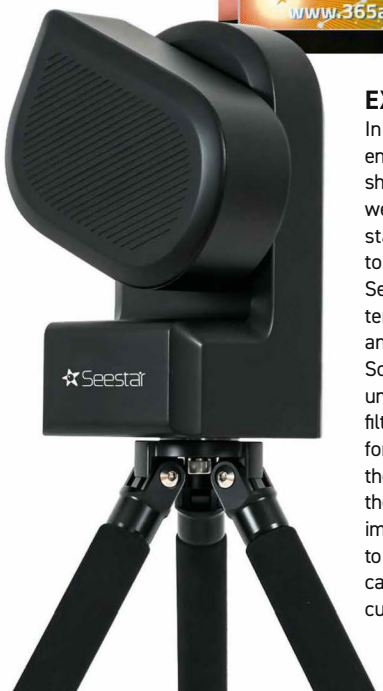

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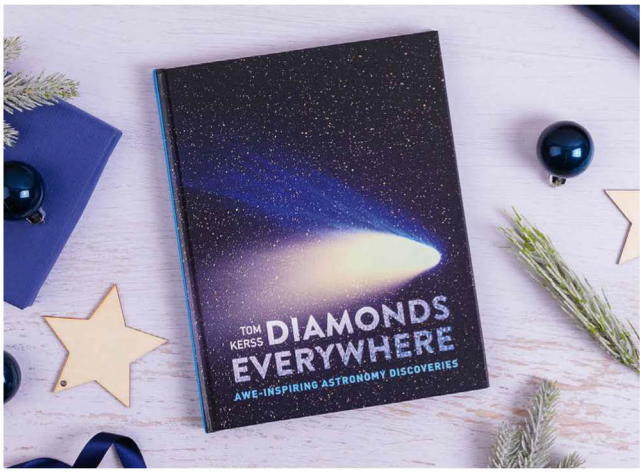

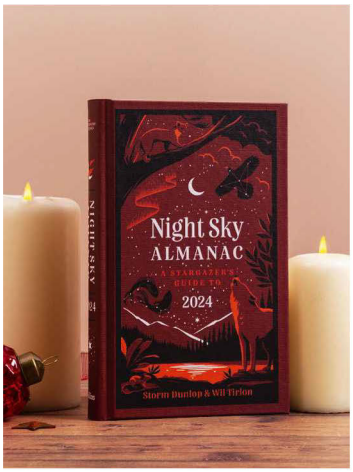

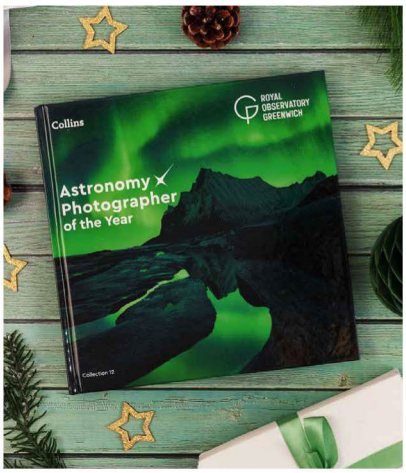

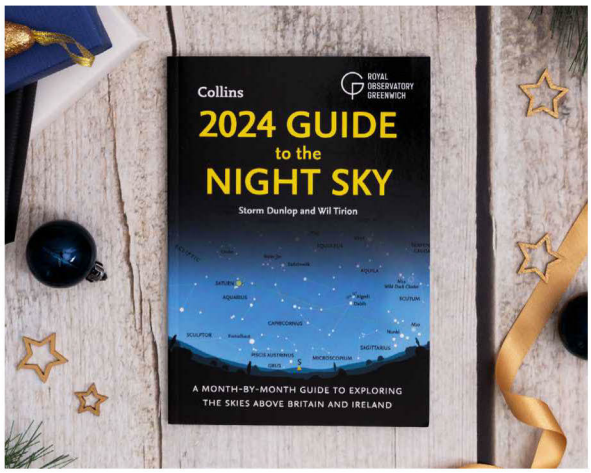

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Feed their cosmic curiosity with ***Diamonds Everywhere*** by Tom Kerss, a stunning photographic guide to 101 facts about the universe.

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Unistellar's eVscope 2 and eQuinox 2 smart telescopes bring the wonders of the universe closer to amateur astronomers and space enthusiasts.

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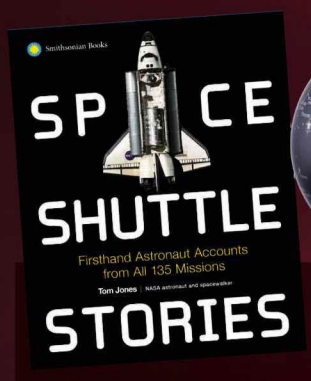

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HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★½ Very good
★★★½ Good ★★½ Average ★½ Poor/avoid

@THESHED/PHOTOSTUDIO

FIRST LIGHT

Ursa Major 6-inch f/8 Planetary Dobsonian

A decent option for would-be planetary observers on a limited budget

WORDS: CHARLOTTE DANIELS

VITAL STATS

- **Price** £269
- **Optics** Newtonian reflector, 152mm (6-inch) parabolic primary mirror
- **Focal length** 1,200mm, f/7.9
- **Mount** Dobsonian with spring tension control
- **Extras** 1.25-inch 9mm and 25mm Plössl eyepieces, finderscope
- **Weight** 23kg
- **Supplier** First Light Optics
- **Email** questions@firstlightoptics.com
- **www.** firstlightoptics.com

The Ursa Major 6-inch f/8 telescope is part of a family of budget-friendly Dobsonians, ranging from 80mm to a substantial 8-inch. This model is offered as a planetary option, thanks to its long focal length of 1,200mm, and we were keen to see whether the optical quality promised by the coated, high-reflectivity primary mirror (guaranteed at least 93 per cent reflective) would support this.

The Ursa Major arrived in two boxes, one for the optical tube assembly (OTA) and the other for the wooden mount, which was flat-packed and so required assembly. The assembly instructions are on the First Light Optics website. We found them easy to follow and had it built within 30 minutes.

Inspecting the setup, the feel of the telescope is as we'd expect for a budget Newtonian. We were impressed with the look of the focuser and the finderscope bracket, both of which exceeded expectations. The mount and base were robust, although it took a few tweaks to get everything fitting together. For example, the side panels needed a few adjustments for the OTA to cradle properly. We also played about with the side bearing spring system. However, this fine-tuning didn't take long.

A selection of accessories are supplied to get beginners started: two eyepieces, one a low-powered 25mm and the other a higher-magnification 9mm, both Plössl and 1.25-inch fit, along with a finderscope.

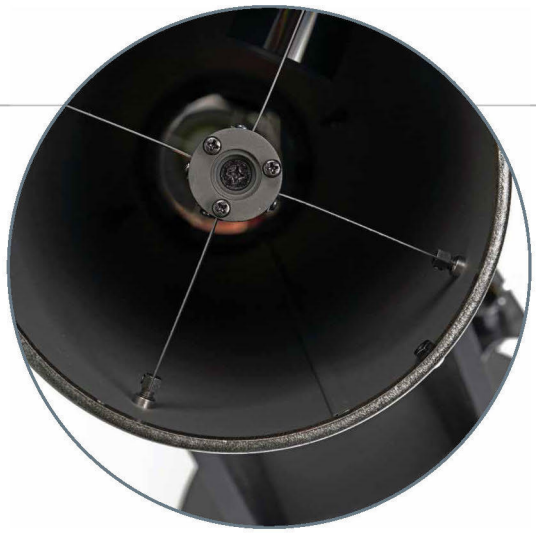
It's best to carry the OTA and mount separately so we were careful not to put our eyepieces in the tray until outside. Under clear autumn skies, we examined collimation. Popping the 25mm eyepiece in, we were pleased to note the Ursa Major arrived near-perfectly collimated – a rare yet brilliant discovery! Collimation is one of the trickier aspects of a reflector and can prove quite a hurdle for beginners. While we did do a minor collimation to put the optical system through its paces, the OTA could certainly be used without it.

Looking at the bright star Vega, we saw minimal colour fringing or diffraction spikes. The stellar ▶

Built for beginners

The 6-inch aperture and 1,200mm focal length of this Newtonian are an excellent choice for a first telescope. As a reflector, the 6-inch aperture collects enough light to provide pleasing views of a wide range of astronomical objects, while remaining compact enough to still be portable. These attributes help to encourage newcomers to astronomy, as they won't be limited to just observing the Moon: detailed and inspiring views of galaxies, star clusters and planets can also be enjoyed.

The Newtonian optical design also gives beginners access to higher magnifications, allowing close-up views of nebulae that would appear much smaller if using a refractor of a similar price. This gives plenty of scope for users to enjoy this reflector even once they've become more experienced as visual astronomers. Ursa Major has carefully considered the design of this Dobsonian to ensure



it is simple to collimate, with easily adjustable collimation knobs on the outside of the tube. This makes a tricky technique straightforward for beginners and allows them to get the best optical experience from this budget reflector.

ALL PICTURES: @THESHED/PHOTOSTUDIO

SCALE

6x30mm finderscope

A finderscope is essential for finding your way around the night sky and Ursa Major's Dobsonian comes ready with a mounting slot on the tube and a metal bracket to attach the straight-through finderscope. Tension screws enable you to adjust its position to suit.

1.25-inch Crayford focuser

The CNC-machined, single-speed focuser comes with two tension adjustment knobs to provide excellent focus control while being easy to use. These also ensure that the focus doesn't slip if using heavier eyepieces. The diameter is suitable for a wide range of 1.25-inch eyepieces, Barlow lenses and other accessories.

Accessories tray

Swapping out eyepieces can be difficult if you're having to rifle through a bag in pitch darkness. The easy-to-access eyepiece tray at the side of the mount makes changing between accessories easy, while limiting the risk of damaging or losing them.

Carry handle

Budding astronomers often want to transport their new telescope to dark-sky sites or local astronomy societies in order to get to know their kit. The carry handle, securely attached to the sturdy mount, allows it to be easily transported to different locations and to last-minute observing sessions when clear skies appear.

FIRST LIGHT

The Moon, as shot using the 25mm eyepiece and a smartphone

KIT TO ADD

1. Astro Essentials 1.25-inch 2x Barlow with T thread

2. Astro Essentials Moon filter 1.25-inch ND 0.9

3. Astro Essentials Cheshire collimating eyepiece

► views were very good, although we did see some elongation of stars towards the edges of the field of view (FOV). This isn't surprising for a budget telescope, and certainly this 6-inch reflector gave excellent early impressions. The movement of the focuser was fluid, even at its single speed. It still felt like we had a lot of focus control.

We then moved to a more stringent test of the resolving power, heading over to the Double Double, Epsilon Lyrae. The mount was easy to move as we travelled between objects. Inserting the higher-powered 9mm eyepiece, we resolved crisp and beautiful views of the four stars in the system. We will highlight, however, that it is too easy to move the base from left to right, knocking the FOV once on an object. This means extra care should be taken, which may prove tricky if viewing with young ones, who tend to grab eyepieces.

Having performed well in star tests, we took advantage of the dark night to take a look at M31, the Andromeda Galaxy. We could easily see the very bright core and its satellite galaxies via the 25mm eyepiece. As this is a planetary telescope, however, it was time to head to Saturn. Through the 9mm eyepiece the planet appeared crisp and clean, with a clear gap between the disc of the planet and its rings.

We had been pleasantly surprised with the optical capabilities of the Ursa Major 6-inch system, and several nights later we were back out to view a full supermoon. While it was too bright to enjoy crater details, we could see that the 25mm eyepiece provided very little to no colour fringing. Popping our smartphone carefully over it, we took a lovely photo of the Moon to document our session.

All in all, the Ursa Major outperforms many of its competitors in the same price bracket and should keep fledgling astronomers encouraged and engaged while they scope out their interest.

360° rotating Dobsonian mount

The wooden rotating base is well designed, with a roller-bearing assembly to aid sideways adjustments and metal plates sandwiched between the bases to keep action smooth throughout each session. Teflon pads allow you to gently alter the altitude of the OTA, and the spring tension system provides more resistance.

VERDICT

Assembly	★★★½☆
Build & design	★★★½☆
Ease of use	★★★★★
Features	★★★★½
Optics	★★★★★
OVERALL	★★★★½

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Our experts review the latest kit

FIRST LIGHT

Bresser ISA Space Exploration NASA 70/700 AZ telescope

This beginners' package has everything you need to see the Sun, Moon and planets

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £119.99
- **Optics** 70mm achromatic refractor
- **Focal length** 700mm, f/10
- **Mount** Altazimuth (manual)
- **Extras** Red dot finder, 9mm and 20mm eyepieces, 1.25-inch star diagonal, smartphone camera adaptor, planetarium software download, solar filter, instruction sheet, planisphere
- **Weight** 2.5kg
- **Supplier** Telescope House
- **Tel** 01342 837098
- **www.telescope house.com**

The ISA Space Exploration NASA 70/700 AZ telescope is very much a beginners' telescope package, comprising a 70mm achromatic refractor, manual altazimuth mount, red dot finder, star diagonal, 20mm and 9mm Kellner eyepieces, front-mounted solar filter and smartphone camera adaptor. This comprehensive outfit allows observations of a wide range of celestial objects, from the Moon, Sun and planets through to deep-sky objects. The construction uses lightweight materials throughout, making this telescope suitable as a 'grab and go' instrument with quick deployment at home as well.

The telescope is supplied in a full-colour retail box that enhances the presentation of the outfit as a gift for a budding new astronomer, but there is a glaring error in the printed text in several places. The box erroneously describes the telescope as a 'reflector telescope', which it isn't: it has a two-element lens design, known as an achromatic refractor.

The optical tube has a high-gloss white finish with a red pinstripe around the base of the dew shield. The optical tube and dew shield are made from seamless aluminium with a very matt black internal finish to reduce reflections. To further reduce reflections, a single knife-edge baffle is employed within the tube. In use, the dew shield did a commendable job of keeping dew from forming on the front element of the primary lens.

Assembly of the various components was very quick, as the mount is pretty much fully assembled straight from the box and a pictorial assembly sheet is included for reference. The telescope is attached to the mount via a yoke mounting, designed to allow observations at the zenith if required, with altitude adjustment made by tilting the telescope by hand and then clamping an adjustment rod into position. The adjustment rod has a knurled thumbwheel with a long internal thread for making small altitude adjustments to centre objects vertically in the view. Unfortunately, there is no fine adjustment for azimuth and the very action of adjusting focus causes the view to bounce all over the place, which was a bit frustrating at times. ▶

Simple solar observing

The telescope comes with a front-mounted solar filter. It is imperative that filters like this are securely attached to the front of the telescope with no risk of them being dislodged, to ensure the protection of your eyesight. This filter is securely mounted within a yellow plastic ring that in turn fits firmly inside the front of the dew shield, making it very safe if it's used carefully (and only under adult supervision if children are going to be using the telescope).

This type of filter has a reflective surface that cuts out about 99.99 per cent of the light passing through it. Such filters allow you to observe the Sun's visible surface, the photosphere, in 'white light', making it possible to discern the texture of this layer, known as granulation, and features like sunspots. In common with some similar filters, this one has an additional layer that imparts a false yellow-orange tinge to the Sun, to produce an image with the colour that many observers would expect to see.

ALL PICS: @THESHED/PHOTOSTUDIO

Optics

The achromatic doublet glass lens has a single coating of magnesium fluoride, representing the minimum treatment required to combat unwanted reflections. The two lens elements in this design are made from different glass types and are designed to minimise the coloured halos around bright objects caused by chromatic aberration.

Eyepieces and focuser

The 20mm and 9mm Kellner eyepieces provide magnification of 35x and 77x respectively and include fold-down eyecups and filter threads. The 20mm was perfectly adequate for beginners, though the 9mm was not quite as good. The simple, plastic, single-speed, rack and pinion focuser is pleasantly smooth to use.

Yoke mount

At the top of the tripod is a traditional yoke mount that supports the telescope so that it can move both vertically and horizontally. The yoke design is raked rearwards towards the eyepiece and focuser so that the telescope can be aimed at objects high in the sky without fouling the tripod legs.

Tripod

The aluminium and plastic tripod is extremely light to transport but stable enough for a small telescope like this. There is a plastic tray-style leg spreader that has useful cut-outs for your eyepieces and other accessories. The aluminium legs allow for height adjustment of the telescope tube from 73cm to 115cm.

FIRST LIGHT

The Moon, taken with an iPhone 5s using the 20mm eyepiece and smartphone adaptor

Close-up of sunspots, this time using the 9mm eyepiece

▶ To the rear of the optical tube, just forward of the focuser, there is a mounting bracket with a sprung retaining tab for the supplied red dot finder. To assist further in the search for objects, there is a waterproof planisphere and a QR link to download the excellent Stellarium planetarium software for iPhone and Android smartphones or for Windows, Mac and Linux computers, for planning an evening's observing session.

Deep-sky challenge

We tested the telescope on a wide range of objects, including Jupiter, with its gorgeous pin-prick moons, and Saturn, which was just a few days past opposition, clearly observing its ringed nature. Views of the Moon were very enjoyable despite a small amount of chromatic aberration being visible on the limb. We also viewed the Sun (using the supplied solar filter) and were delighted to easily observe sunspots AR3415, AR3417, AR3421, AR3422 and AR3423.

With some Solar System objects in the bag, we went in search of deep-sky targets, observing the colour-contrasting binary Albireo in Cygnus, globular clusters M13 and M92, and the lovely bright star Vega. We also observed Epsilon Lyrae, the well-known Double Double multiple star system in Lyra, and tracked down the large Andromeda Galaxy, M31. With the review period encompassing late summer, we used the bright star Deneb in Cygnus as our optical test star and found good star shapes out to just over 80 per cent of the field of view using the 20mm eyepiece.

Included in the kit is an eyepiece projection adaptor for a smartphone that we used to capture images of the Moon and Sun with our iPhone 5s, using the 20mm eyepiece for whole-disc images and the 9mm eyepiece for zooming in a little closer. We found the adaptor to be rather fiddly to use, especially when imaging the Sun, but with a bit of patience it did work.

We were generally pleased with the performance of Bresser's ISA Space Exploration NASA 70/700 AZ telescope. Although soon outgrown, it will make an ideal first telescope for astronomy beginners on a tight budget.

Red dot finder

The rather basic red dot finder supplied with the telescope has a dual-intensity LED. Its virtual position on the sky can be adjusted using horizontal and vertical adjustment thumb screws. However, the finder's lightweight construction and the way it's mounted made it rather flimsy in use.

VERDICT

Assembly	★★★★☆
Build & design	★★★☆☆
Ease of use	★★☆☆☆
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★☆☆

KIT TO ADD

1. Bresser 6.5mm Plössl eyepiece

2. Bresser 1.25-inch 2x Barlow lens

3. Explore Scientific Filter Set 1: Moon & Planets

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Baader H-alpha f/3 highspeed filter

Price from £229 • **Supplier** The Widescreen Centre
www.widescreen-centre.co.uk
Available in a range of sizes, this astrophotography filter is designed for fast telescopes between f/3.4 and f/2.3. Many filters struggle with shorter focal lengths, resulting in unwanted colour shifts, but this high-speed version will give a consistent view across the frame.

2 Altair telescope cover

Price from £58.50 • **Supplier** Harrison Telescopes
www.harrisontelescopes.co.uk
Protect your telescope from the elements with a cover made from waterproof and UV-proof fabric. Its silver colouring also reflects heat, keeping your scope cool during the daytime. Available in a range of sizes.

3 Celestron Starsense Autoguider

Price £749 • **Supplier** Tring Astronomy Centre
www.tringastro.co.uk
ADVANCED Improve your Go-To mount's precision with this autoguiding system. The Starsense will align your scope in just three minutes with a single button and keep your target in the centre of the view all night long.

4 Omegon polar finder light for MiniTrack and EQ mounts

Price £52 • **Supplier** Astroshop.eu
www.astroshop.eu
Simplify aligning your equatorial mount with a polarscope light that uses a red LED to illuminate the guidelines and scales of your polarscope, which can be hard to see in the dark. Brightness is adjustable.

5 Mova 4.5-inch silver and black constellation globe

Price £199 • **Supplier** David Shuttle
www.davidshuttle.com
Watch the stars move across the night sky of this self-rotating globe, which depicts all 88 constellations as well as the path of the Milky Way. It's powered by hidden solar cells.

6 Smartwool men's all-season half-zip base layer top

Price £63 • **Supplier** Blacks
www.blacks.co.uk
Layering up is the key to staying warm throughout a long observing session. This lightweight men's base layer is made from a special Merino jersey fabric for increased comfort and warmth, with a nylon core to ensure durability.

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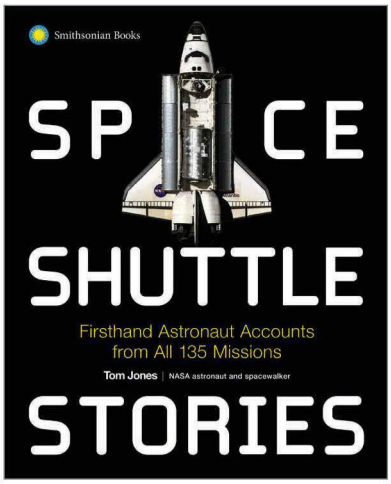
BOOKS



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SHUTTLE HISTORY

Adventure stories are best told by those who lived them. Here, astronaut Tom Jones offers an off-piste look at the 135 Shuttle flights between April 1981 and July 2011. Jones flew four times on the Shuttle, performing spacewalks and helping to build the International Space Station.

Each mission's tale is related by at least one of its crew. Missions appear in date order, with minutiae of numbers, names, durations and crew members in side boxes. Stories are enriched by a glorious image selection.

The book's true nuggets, though, are the astronauts' recollections. It's otherwise hard to find new insights into this fleet of reusable spaceships, which facilitated America's human space programme for a generation.

"Get five astronauts in a room," joked Shuttle commander John Creighton, "and you'll get six opinions." There are opinions and thoughts aplenty here. We learn of super-serious David Low finally laughing after a job well done, Dave Walker dropping his sunglasses as he commanded a Shuttle through re-entry, and Ellen Ochoa shutting an eye at booster separation to ensure she was dark-adapted to read the cockpit instruments during a night launch.

We learn of the forces of lift-off, the glittering lights of Earthly cities and aviators brought to tears by the beauty of the home planet rotating below. David Hilmers remembers getting barred from breakfast duty, Bob Springer relates his agony at a lost spacewalk, Fred Gregory tells of classified medals given and hurriedly taken away, and Bob Crippen, asked which part of a Shuttle mission he liked best, retorts: "The part between lift-off and landing!"

But danger was never far away. As well as the tragedies of Challenger and Columbia, we learn of near-catastrophic tile damage on STS-27, how STS-34's pilots solved a time-critical malfunction seconds after launch, and of a refrigerator leak on STS-40 that could have killed the crew.

Tom Jones on the flight deck of the Space Shuttle during his astronaut training in the early 1990s

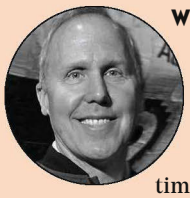
Astronauts, by definition, are usually practical, Type A people and it is rare to see a wordsmith of Jones's ability among their ranks. A key delight in this book is seeing the humanity behind their words. "Make your life count," said Challenger's Ellison Onizuka, "and the world will be a better place because you tried." ★★★★★

***Ben Evans** is the author of several books on human spaceflight*

NASA

Interview with the author

Tom Jones



What are your favourite memories of the Shuttle?

It was the best job ever! I was lucky enough to fly four times. We encountered a few problems but I never forgot how miraculous it was to live and work in a spaceship that kept us safe in orbit for weeks. Most memorable were my crewmates, who kept me laughing for 53 days while we accomplished some amazing science. Close second was the ever-changing view of our home planet from orbit.

How do you feel about the retirement of the ISS?

I'm gratified the Destiny science lab we delivered to ISS, designed to last 15 years, is going strong 22 years later. Eventually, structural fatigue and obsolete systems will dictate the ISS's retirement. Some newer elements will be recycled into future commercial stations like Axiom and others will be new builds with a mix of tenants. Meanwhile, NASA's new Gateway will serve as a lunar orbit outpost.

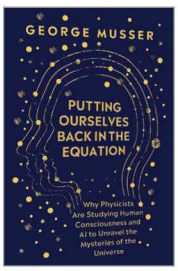
Where should we be focusing our space exploration efforts?

Our goal should be returning to the Moon with humans. Working with AI-driven robots, lunar explorers will take the first steps in tapping its resources to expand our economic reach. We should tap the hundreds of millions of tonnes of water ice in craters at the poles, producing oxygen, rocket propellants and drinking water. Lunar propellant may fill the tanks of future Mars expeditions. The challenges of water extraction will build on the skills we honed on the Shuttle. Our graduation will be sending a team of explorers to prospect Mars for life.

***Tom Jones** is a scientist, speaker, pilot and veteran NASA astronaut*

Putting Ourselves Back in the Equation

George Musser
Oneworld
£25 ● HB



What is the nature of human consciousness? This question has occupied many of the greatest minds since time immemorial. But what do science and technology have to say on the subject? This book aims to present current theories on the mechanisms of the mind and its interaction with the Universe.

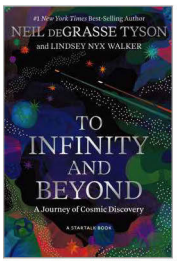
The author explores topics such as neural networks, quantum computing, artificial intelligence, neuroscience, information theory and cosmology. Although well presented and interspersed with copious notes from leading proponents, the book can be hard going for the uninitiated. Part of the problem is that some of these topics occupy that shady area between philosophy and science, and are to some extent esoteric and speculative. We are left with no adequate consensus; we are even led to believe that facts don't truly exist. Despite this, the author does a fine job of pulling together the various ideas in an easy-to-read narrative. If you're interested in how your mind works, what its limitations are and how it connects to the rest of the cosmos, it's a fascinating read.

Perhaps the primary revelation of this book is that we are still no nearer to understanding the origin and mechanism of human consciousness than the ancient philosophers were. Another major take-away is that reality itself is a construct of the mind, not of any physical description of the Universe. That's a sobering thought. Then again, perhaps this book itself is just a figment of the reader's imagination! ★★★★★

***Alastair Gunn** is a radio astronomer at Jodrell Bank Observatory, Cheshire*

To Infinity and Beyond

Neil deGrasse Tyson and Lindsey Nyx Walker
National Geographic Society
£24.99 ● HB



As every traveller knows, the quality of a journey depends on the knowledge and the communication skills of the tour guide. And for "a journey of cosmic discovery" (the subtitle of this gorgeous book), you couldn't wish for a better tour guide than Neil deGrasse Tyson, arguably the best astronomy communicator since the late Carl Sagan. Over some 300 pages, lavishly adorned with great photos and explanatory diagrams, he and co-author Lindsey Nyx Walker take you on a trip from the planet beneath your feet to the very edges of space, time and knowledge.

The book starts with an inspiring history of spaceflight, from the Greek myth of Icarus to the futuristic concept of a space elevator, with ample background information about our planet's atmosphere. Next, deGrasse Tyson and Walker take us on a tour of the Solar System. Parts three and four focus on the wider Universe and mind-boggling concepts like wormholes, time travel and the multiverse. Boxes and sidebars delve into topics like science history, cosmic conundrums and Hollywood astronomy.

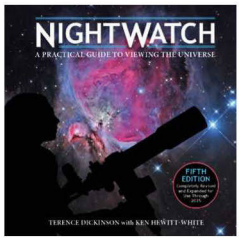
While the book is a little unbalanced – the first half is a literal 'journey' through the Solar System, while the second half is more theoretical – the authors' easy-going style is impressive. It's as if the two of them are sitting next to you, sharing everything they know, fluently tying together very different astronomical topics and not holding back on tough concepts such as general relativity and quantum physics.

A great introduction for astronomy novices and a useful refresher course for every amateur astronomer, this book provides an unforgettable journey of cosmic dimensions. ★★★★★

***Govert Schilling** is an astronomy writer and author*

Nightwatch: A Practical Guide to Viewing the Universe

Terence Dickinson and Ken Hewitt-White
Firefly
£20 ● HB



This field guide to the Universe is not only the ideal first book for any aspiring amateur astronomer, it's the ideal second and third book, too – and this updated fifth edition doesn't disappoint.

In a world of overwhelming data on smartphones and astronomy apps, and with websites hard-selling telescopes galore, what is needed is a book offering a jargon-free, step-by-step journey into what can realistically be seen in the night sky, along with some practical guidance as to how best to achieve this goal. *Nightwatch* is that book. Its main tenet? Hold off purchasing that first telescope. First, identify the constellations with the naked eye using its excellent all-year, battery-free star atlases. Grasp sky motions and stellar magnitudes, then purchase the right binoculars. Having mastered the bins, you can then follow the authors' unfussy advice and invest in the right first telescope – one that will not overwhelm but instead reveal what can really be seen and enjoyed.

Its robust hard cover and ring-binder allow the book to handily fold back on itself. Inside, it is sensibly structured, expertly written in an accessible style, and benefits from spectacular new images. A superb introduction to the minefield of astrophotography will energise rather than befuddle, and a handy resources section at the rear will guide any budding astronomer onward.

This book will not idle on a bookshelf. It's an enjoyable armchair read, but will also become a perennial dew-drenched companion, the one you reach for first. ★★★★★

***Jane Green** is an astronomer, science writer, author and broadcaster*

Ezzy Pearson interviews Jon Culshaw

Q&A WITH AN ECLIPSE CHASER

On 14 October 2023, an annular eclipse passed across mainland USA. Comedian and stargazer **Jon Culshaw** was there to witness it

When did you arrive in the US to watch the eclipse?
I arrived in Roswell, New Mexico on 12 October. The greeting was all I could have hoped for – the airport and most of the town was adorned with green, almond-eyed aliens and mercury-coloured flying saucers! Just before dawn on eclipse day, we set out on an unforgettable road trip to Albuquerque to catch full annularity.

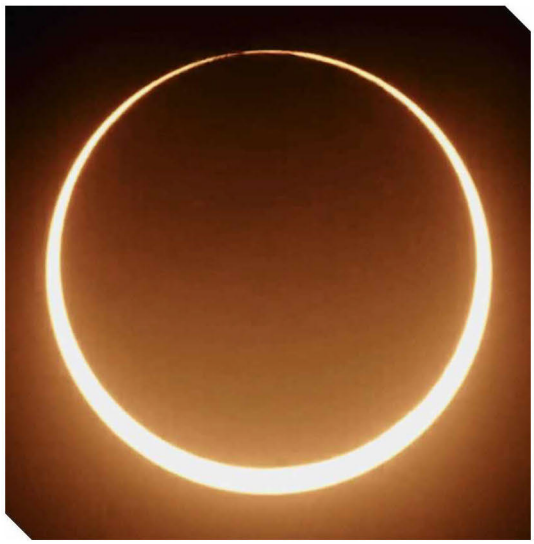
How was the trip to the viewing site?
Venus shone pin-sharp above the deep ochre and electric-blue skies. The Albuquerque Balloon Festival was under way at the time, and the sight of 20 or more hot air balloons – like a vivid, floating candy store – was a magnificent curtain-raiser for the astronomical clockwork set to unfold. Our taxi spotted a patch of waste ground at the side of Route 66 and we turned in.

Twenty minutes later and that first 'bite' out of the Sun began to appear. First contact was right at the top of the Sun, in the 12 o'clock position. From there, things happened quickly. The partial phases pushed forward, blotting out a pair of sunspots as they made their silent, unstoppable celestial progress.

What was it like experiencing the eclipse?
When about 15 per cent of the Sun remained, I was fascinated to see the effect on the heat and light of the day. The warmth of the American morning had now been cut off and there was a subtle difference to the daylight. It was as though the sunshine had had thinners added to it, like a grey gel filter placed in front of a theatrical spotlight. The differences were less marked than with a total eclipse, but they were there nonetheless, and fascinating.

What was the moment of annularity like?
The part of the annular eclipse that will remain in my memory forever occurred at 10:35am MDT. The crescent of the Sun evolved to be a horseshoe, then a sickle. The horns of this thin curve of sunlight gradually reached towards each other until an effervescent, silk-thin line of light sizzled through the topography of the Moon's surface, creating ruby glints as the Sun peeped through. What a unique and beautiful way to behold Baily's beads! Then came the most spectacular moment of all: the two tips of sunlight delicately joined together like a stellar version of Michelangelo's *Creation of Adam*.

This was when the eclipse took on the form of the 'ring of fire'. Annularity is absolutely awe-inspiring! I couldn't help feeling sorry for the drivers passing by, who seemed oblivious to the spectacle taking place.



▲ **Jon's photo just a few moments before perfect annularity, captured in New Mexico, USA, on 14 October**

How long did the experience last?
Annularity remained steady and stunning for five beautiful minutes. I observed every moment, not wishing to take my eyes away from the view through solar binoculars. I did notice the shadows through the rough shrubs, though. They showed innumerable rings, as though the trees were adorned with Christmas baubles. Then Baily's beads appeared again at the base of the Sun, delicately breaking the line of sunlight around the Moon and marking that annularity was over. Such fleeting mesmerisation! It's always a profound feeling immediately post-eclipse: a peaceful euphoria, a new lifelong memory forever etched into your being.

What did you do afterwards?
With the second act of the partial phase under way, we headed back towards Roswell. An hour later, we stopped at a gas station and I took one final look through the solar binoculars. A little bite out the Sun at the 7 o'clock position was all that remained. I always make sure to observe these last moments: it's a way of saying goodbye to the eclipse.

The next day, I was reflecting on the experience during a stroll around Bottomless Lakes State Park outside Roswell – a collection of lakes formed from underwater springs filling huge areas of subsidence. The area looks like the perfect hybrid of Earth and Mars, and a verse for the eclipse came to mind...

The Sun and the Moon are dancing,
Circles in the Sky,
The shadow is advancing,
But the Dragon passes by.
And when the dance is over,
At the end of Sol's dark night
Great mystery reveals itself,
And the darkness turns to light.

Jon Culshaw is an actor, comedian and impressionist. A keen amateur astronomer, he has appeared on BBC's *Stargazing Live* and *The Sky at Night*

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THE SOUTHERN HEMISPHERE

With Glenn Dawes

Get ready for favourable Geminids and discover spectacular sights near the Small Magellanic Cloud

When to use this chart

1 Dec at 00:00 AEDT (13:00 UT)
15 Dec at 23:00 AEDT (12:00 UT)
31 Dec at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

DECEMBER HIGHLIGHTS

The Geminids are among the finest and most reliable of the annual meteor showers. Active from 7 to 17 December, they peak on the 14th. The radiant is low in the north (near the Twin stars Castor and Pollux), but it's well placed in the early morning hours, crossing the meridian around 2am. With a new Moon on the 13th, there will be no lunar interference. The Geminids produce bright, medium-speed meteors and have peaked at 100-plus meteors per hour in past years.

STARS AND CONSTELLATIONS

If the Milky Way passing overhead in all its glory is typical of winter, then the Clouds of Magellan, high in the south, are indicative of summer. Above the small cloud is the first-magnitude star Achernar. Flanking it are Canopus (in the southeast) and Fomalhaut (southwest), the three forming an equidistant straight line separated by 40°. Left (south) of Fomalhaut, lies the distinctive Grus constellation, another of the few markers to this barren, far-southern sky.

THE PLANETS

Mercury is visible low in the evening twilight before being lost to the Sun's glare mid-month. Saturn is moving into the northwest sky, setting late in the evening. Neptune trails it, departing around midnight mid-month. Jupiter continues to dominate the evening sky, transiting around the end of twilight. Uranus follows an hour later. Venus remains unmissable, low in the east at dawn. The month closes with Mercury and Mars returning to the morning, low in the dawn sky.

DEEP-SKY OBJECTS

Starting from Achernar, move 10° southwest to discover Beta 1 and 2 (β^1 and β^2) Tucanae (RA 0h 31.5m, dec. −62° 58'), consisting of two nearly matched 4th-magnitude stars, pale blue and white respectively, separated by 27 arcseconds. They have a fainter mag. +5 companion Beta 3 (β^3) 9 arcminutes away, making Beta Tucanae a good binocular double as well (and it's visible to the naked eye under dark skies too!).

On the western edge of the Small Magellanic Cloud (SMC) lies the spectacular globular cluster NGC 104, better known as 47 Tucanae (RA 0h 24.1m, dec. −72° 04'). Second in brilliance only to Omega Centauri, this mag. +4.1 citadel of stars is naked-eye visible. It has a large halo (0.4° across) with stars easily resolved on the edge. Its extremely bright core shows numerous stars spread across its background glow – awesome!

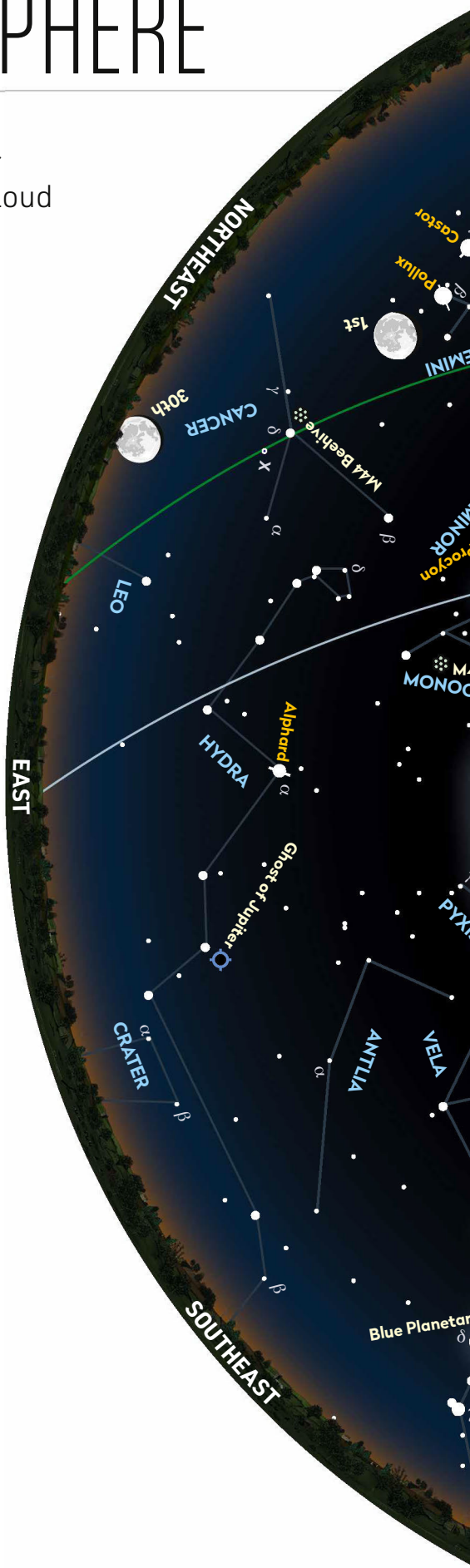

Chart key

- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- COMET TRACK
- ASTEROID TRACK
- METEOR RADIANT
- QUASAR
- PLANET

STAR BRIGHTNESS:
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
Capella
AURIGA
PERSEUS
Algol
Almach
M34
NGC 752
ANDROMEDA
TRIANGULUM
M33
California Nebula
M36
M37
27th
24th
Pleiades
M35
Aldebaran
Hyades
Hamal
ARIES
Uranus
PEGASUS
PISCES
Great Square of Pegasus
ORION
Betelgeuse
Jupiter
21st
TAURUS
Menkar
Alrescha
Ecliptic
M78
Rosette
M43
M42
Rigel
Mira
Celestial Equator
Winter Triangle
M50
Sirius
CANIS MAJOR
CETUS
Neptune
Ceiel
LEPUS
M41
M47
ERIDANUS
PUPPIS
COLUMBA
CAELUM
HOROLOGIUM
NGC 253
Denebb Kaitos
AQUARIUS
18th
Canopus
DORADO
PICTOR
CARINA
PHOENIX
NGC 300
SCULPTOR
Fomalhaut
Saturn
Helix
RETICULUM
NGC 1466
Tarantula Nebula
LMC
Achernar
SMC
NGC 362
VOLANS
MENSA
HYDRUS
PISCIS AUSTRINUS
GRUS
Gem Cluster
South Celestial Pole
47 Tucanae
TUCANA
CHAMAELEON
Southern Pleiades
OCTANS
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